DOCUMENT RESUME

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IDENTIFIERS	*Alternators (Electric Generators)

ABSTRACT

This vocational physics individualized instructional student module on the alternator consists of the four units: Current electricity, magnets from electricity, electricity from magnets, and energy conversion. Designed with a laboratory orientation, the units present explanations of the concepts and experiments. Laboratory data sheets, illustrative drawings, review questions, student prerequisites and objectives, and lists of suggested audiovisual materials are also included in the module. (NJ)

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ED131293

FIELD TEST EDITION

THE ALTERNATOR

I. CURRENT ELECTRICITY

II. MAGNETS FROM ELECTRICITY

III. ELECTRICITY FROM MAGNETS

IV. ENERGY CONVERSION

Vocational-Technical Physics Project

Ralph Parsons, Project Director

Forsyth Technical Institute

Winston-Salem, North Carolina

sponsored by

the

Occupational Research Unit

State Department of Education

Raleigh, North Carolina

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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PRE-REQUISITES

Before beginning the module, the student should be able to work the following types of mathematical problems.

1. Given two whole numbers, calculate their product.
2. Given two whole numbers, one a dividend and one a divisor, calculate the quotient.
3. Given two decimal fractions, calculate their sum.
4. Given two decimal fractions, calculate their differences.

The student should also be able to read a mercury-in-glass thermometer.

OBJECTIVES

A. After completing the module, the student will be able to recognize the definitions and applications of the following terms. Testing will be by multiple choice questions.

1. electric potential
2. electric current
3. resistance
4. volt
5. ampere
6. ohm
7. voltmeter
8. ammeter
9. ohmmeter
10. magnet
11. generator
12. alternator
13. diode
14. alternating current
15. direct current
16. oscilloscope
17. energy
18. power
19. joule
20. watt
21. series circuit
22. parallel circuit
23. torque
24. efficiency

B. The student will be able to name the factors that

1. determine the resistance of a material,
2. determine the strength of an electromagnet, and
3. determine the size of an induced voltage.

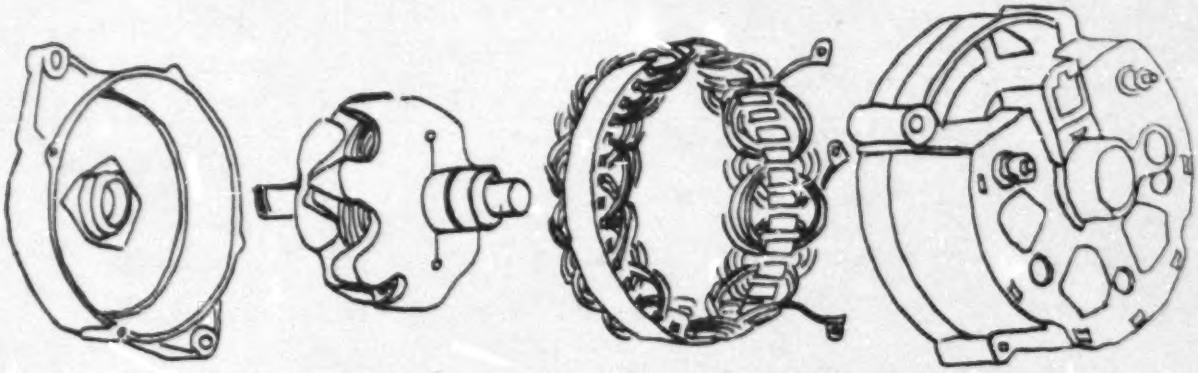
Testing will be fill-in-the-blank questions.

C. The student will also be able to solve numerical problems involving the following quantities.

1. electric current
2. voltage
3. resistance
4. energy
5. power

The system for assigning grades to levels of performance will be determined by the instructor.

The alternator is a small electrical generator. Its main use is to supply the electricity necessary to operate cars and trucks. Anyone who operates or services cars and trucks might benefit from knowing more about the alternator. More important, anyone who understands the alternator will have a good understanding of electricity.



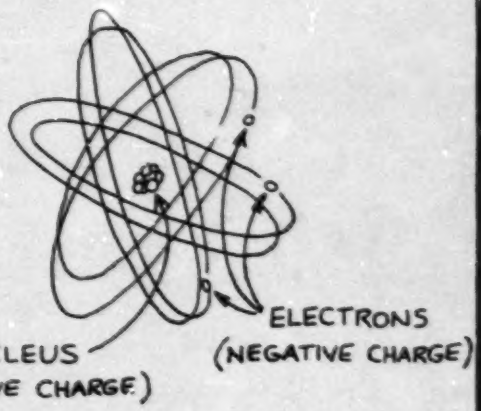
UNIT I. CURRENT ELECTRICITY

Electricity is invisible. It is something that flows through wires, light bulbs, motors, and other electrical gadgets. Sometimes it flows through people-making it somewhat dangerous. To be able to know what to expect from electricity we must use our imaginations (and some atomic theory.)*

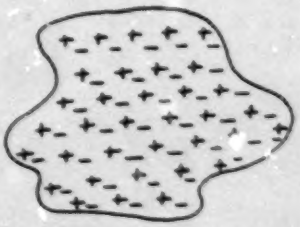
*A theory in science is a guess about the way things are. A successful theory--such as the atomic theory--can be used to predict how things will act in certain situations.

ELECTRIC CHARGES

All materials are made up of atoms. All atoms have the same basic parts. Atoms have a small, heavy nucleus (core) that is surrounded by a number of lighter particles called electrons. Both the nucleus and the electrons have a mysterious property called electric charge.



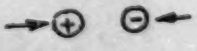
There are two kinds of charge- positive and negative. The nucleus is positive and the electrons are negative. In a normal atom the negative charge of the electrons exactly cancels out the positive charge of the nucleus.



MATERIALS NORMALLY HAVE EQUAL AMOUNTS OF POSITIVE AND NEGATIVE CHARGE

Bodies that have electric charge exert forces on one another. Charges that are the same will repel each other. Charges that are different will attract each other.

CHARGES THAT ARE THE SAME REPEL.



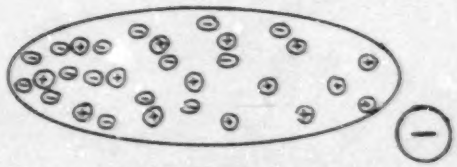
CHARGES THAT ARE DIFFERENT ATTRACT.

The amount of electric charge that a body has is measured in coulombs. Each electron has the same amount of charge and it takes 6,250,000,000,000,000,000 of them to make one coulomb.

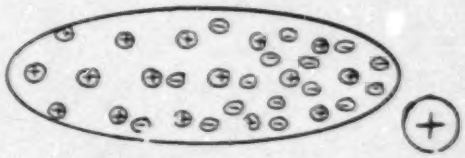
In solid materials the positive charges are fixed in place and move very little. Some electrons, however, are free to move throughout the material. When a charge is brought near a material, the free electrons in that material move. THE MOVEMENT OF ELECTRONS IS CALLED ELECTRIC CURRENT.

Electrons can be moved by other charges without actually being touched. To explain this we say that all bodies are surrounded by invisible electric fields. An electric field fills the space around an electric charge. This field will cause electrons to move away from a negative charge and toward a positive charge.

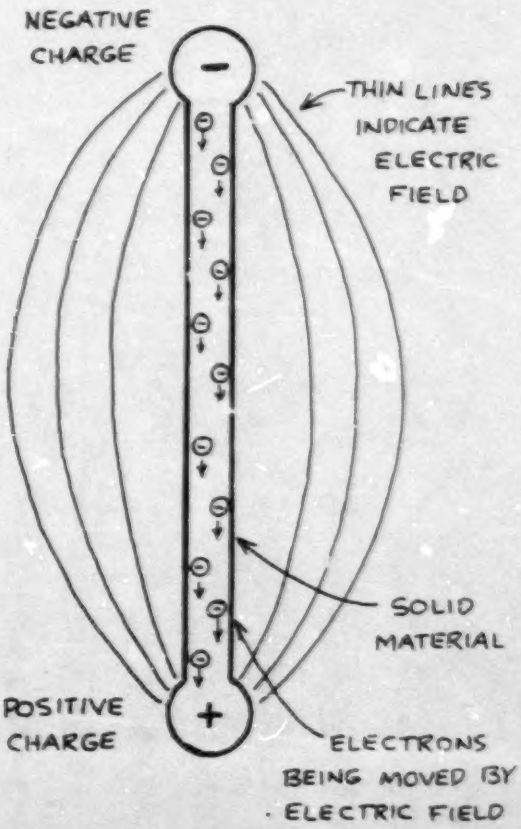
When electrons are grouped together they have electric potential energy. They can do work as they move away from a negative charge toward a positive charge. THE WORK THAT ELECTRONS CAN DO, DIVIDED BY THE AMOUNT OF CHARGE, IS CALLED THEIR ELECTRIC POTENTIAL.



ELECTRONS WILL MOVE AWAY FROM A NEGATIVE CHARGE...



... AND TOWARDS A POSITIVE CHARGE.

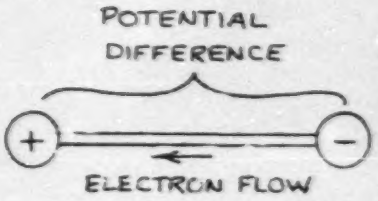


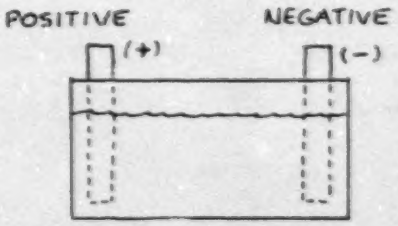
ELECTRIC POTENTIAL

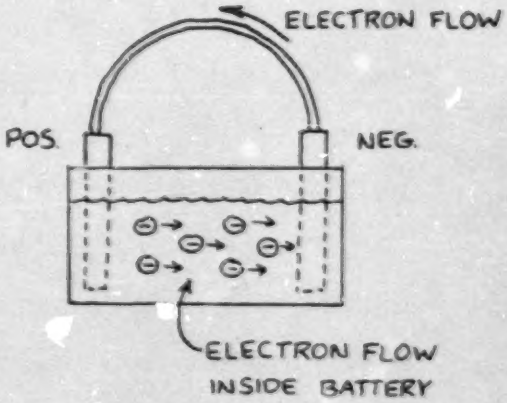
When electrons move through a device that uses electricity, they do work. As they do work, they lose energy (and electric potential). The flow of electrons is always between areas of different potentials. They flow through a potential difference*

A potential difference is often supplied by a battery. A battery is a container of chemicals with two metal terminals. Chemical action inside the battery causes one of the terminals to have a negative charge and the other to have a positive charge. If a material with some free electrons is connected between the terminals, electrons will flow from the negative end to the positive end. When an electron arrives at the positive terminal, the chemicals in the battery place an equal charge on the negative terminal.

The electrons do work, losing energy, as they flow outside the battery. The chemical action inside the battery replaces the energy of the electrons.







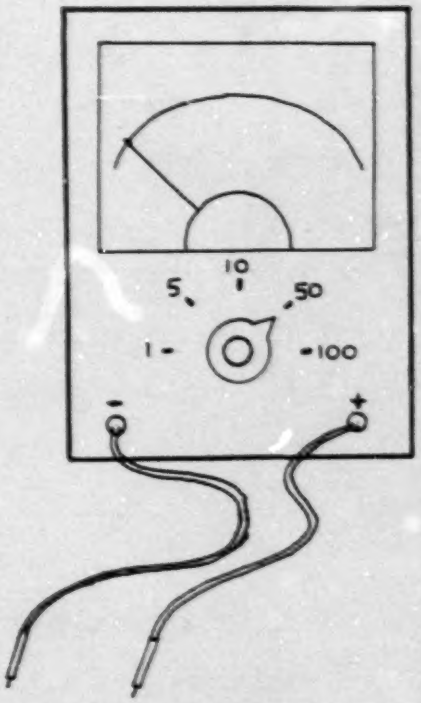
*Electric potential difference, E, is also called electromotive force.

EXPERIMENT NO. I

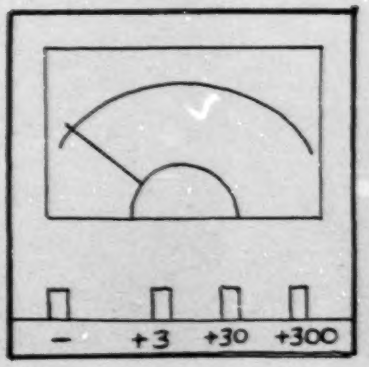
MEASURING ELECTRIC POTENTIAL DIFFERENCE

The purpose of this experiment is to introduce you to the voltmeter and show you how to use it.

ELECTRIC POTENTIAL DIFFERENCE IS MEASURED IN VOLTS. THE DEVICE USED TO MEASURE IT IS CALLED A VOLTMETER. Electric potential difference is such a long term that often it is simply called voltage. A voltmeter is an electric meter with two wire leads. THE VOLTMETER INDICATES THE POTENTIAL DIFFERENCE, OR VOLTAGE, THAT EXISTS BETWEEN THE ENDS OF THE TWO LEADS.



Voltmeters come in many shapes and sizes. They often have more than one range. The range of a voltmeter is the largest voltage that it can measure. If a voltmeter has more than one range it will have a selector switch or a number of terminals to which the leads can be connected.



A general-purpose electric meter known as a multimeter can measure voltages over several ranges.

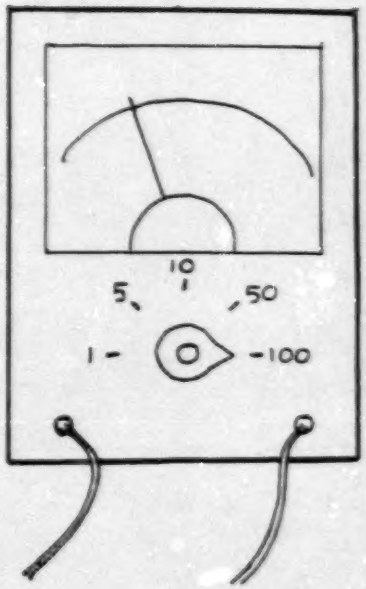
When using a voltmeter there are three rules to remember.

1. Use a range that is larger than the voltage being measured (when in doubt--start with the highest range.)

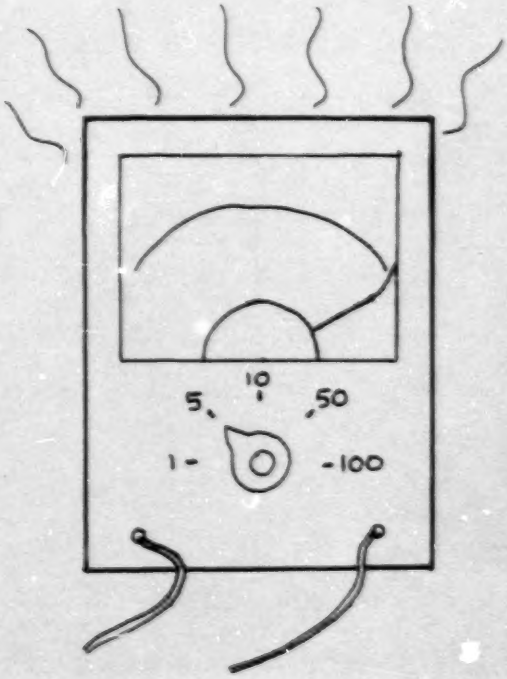
2. Connect the positive (red) terminal of the voltmeter to the positive point of the voltage and the negative (black) terminal to the negative point.

3. If you working with more than 25 volts, don't touch any bare wires.

Neglecting rule 1 or 2 can damage the meter. Neglecting rule 3 can damage your body.



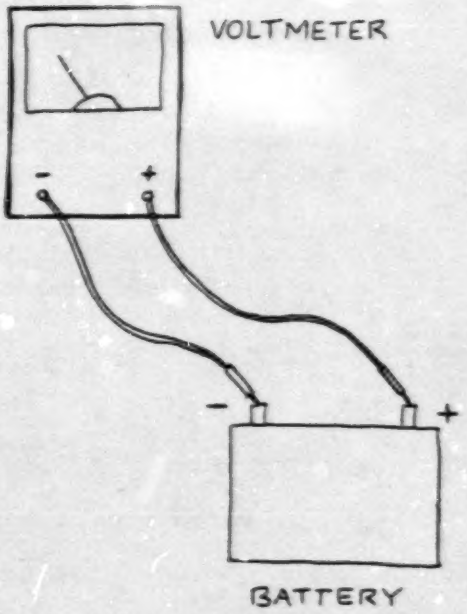
WHEN IN DOUBT USE THE HIGHEST RANGE ...

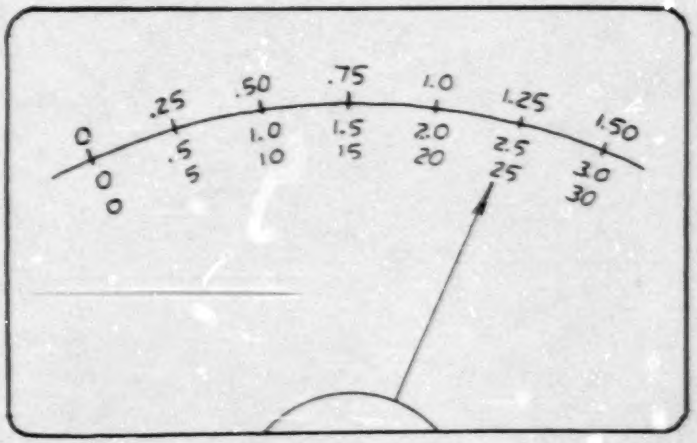


... OR THE METER MIGHT SUFFER.

Using a voltmeter, measure the voltage of several different types of batteries. Use as many different ranges as possible. If different types of voltmeters are available, use all of them. Make a list that describes the batteries and the voltage measured with each voltmeter.

FILL OUT THE LABORATORY DATA SHEET





A VOLTMETER SCALE WITH THREE RANGES

USING THE 1.5V RANGE, THE READING IS 1.0V

USING THE 3.0V RANGE, THE READING IS 2.0V

USING THE 30V RANGE, THE READING IS 20V

ELECTRIC CURRENT

When a voltage exists between two points in a material, free electrons will flow from the most negative point to the most positive point. THE FLOW OF ELECTRONS IS CALLED ELECTRIC CURRENT.* THE CURRENT IS MEASURED IN AMPERES -- USUALLY CALLED AMPS. An ampere is one coulomb per second. When 6,250,000,000,000,000 electrons pass a point in one second, the current is one ampere.

The amount of current in a material depends on two things.

1. The amount of voltage applied-larger voltage causes larger current.

2. The ability of the material to resist the flow of electrons through it. Higher resistance allows fewer electrons to flow.

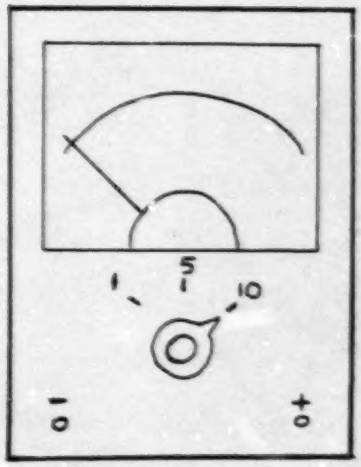
*To be more exact, this is called electron current. You will also see current referred to as the flow of charge from positive to negative. This is called conventional current.

EXPERIMENT NO. 2

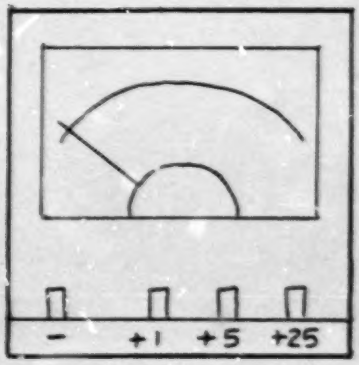
MEASURING ELECTRIC CURRENT

The purpose of this experiment is to introduce you to the ammeter and show you how to use it.

ELECTRIC CURRENT IS MEASURED IN AMPERES (AMPS). THE DEVICE USED TO MEASURE CURRENT IS CALLED AN AMMETER. An ammeter has some of the same parts as a voltmeter. It is an electric meter with two wire leads or terminals. The ammeter measures the current through the meter.



Ammeters come in various shapes and sizes and most of them have more than one range. Multimeters can measure current over several ranges.



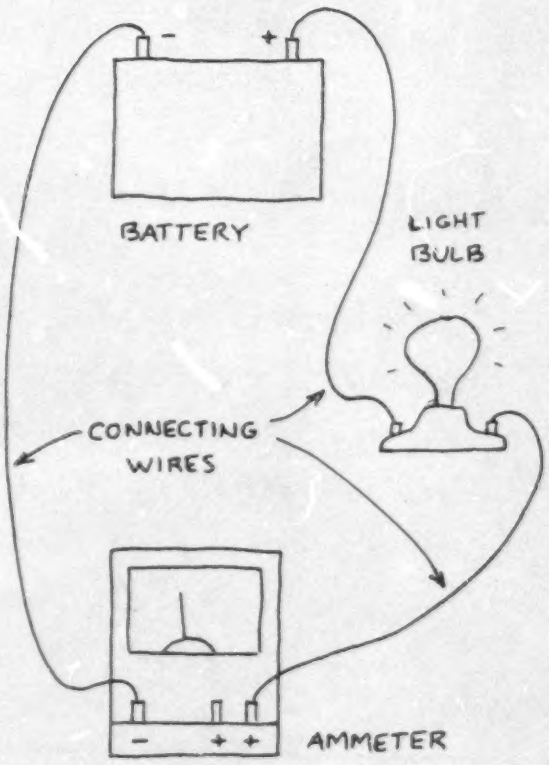
When using an ammeter there are four rules to remember.

1. Use an ammeter to measure the current in a device that uses electricity.

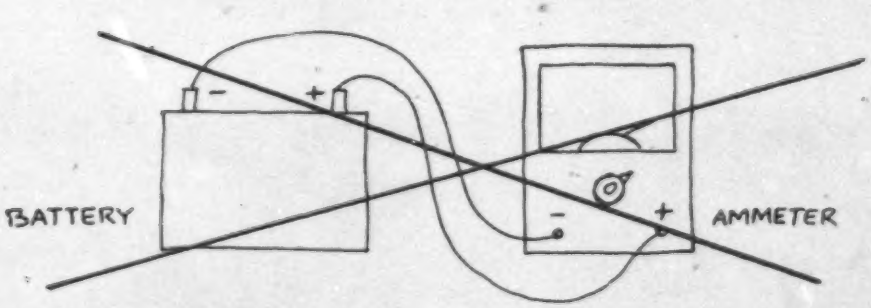
2. Use a range that is larger than the current being measured.

3. Connect the positive (red) terminal of the ammeter to the positive point and the negative (black) terminal to the negative point. (The electrons should flow into the black terminal of the meter and out the red terminal).

4. If you are working with more than 25 volts, don't touch any bare wires.



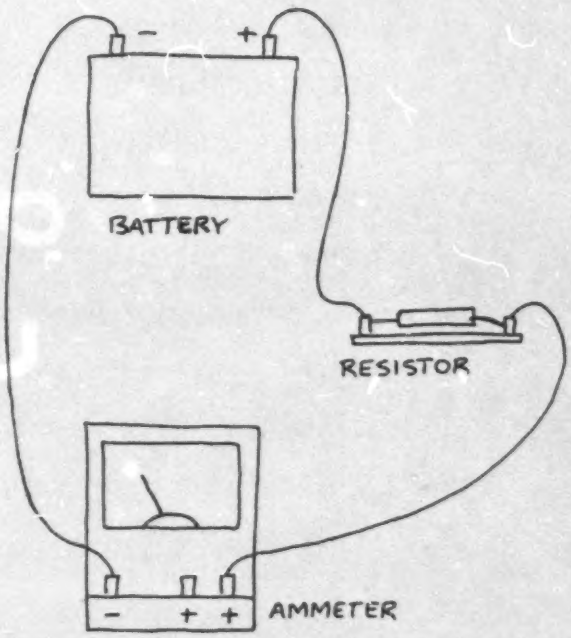
CORRECT CONNECTION OF AMMETER

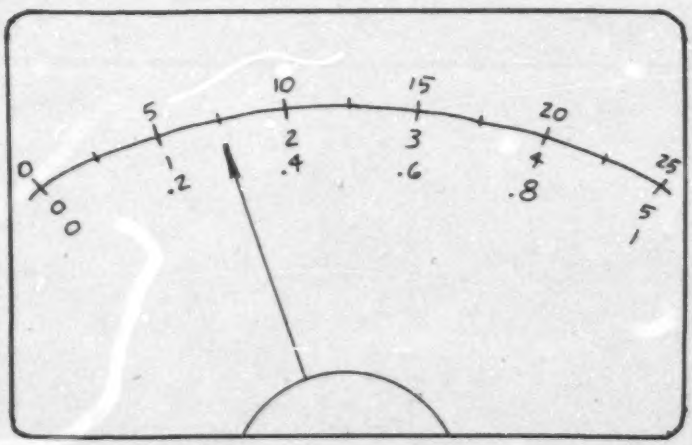


WRONG – THIS WILL DAMAGE THE METER

Using an ammeter, measure the current from a battery to a resistor. A resistor is a device made of a material that resists the flow of electrons through it. Use several different resistors and some different ammeters. Make a list that describes the resistor and the current measured with each ammeter.

FILL OUT THE LABORATORY DATA SHEET





AN AMMETER SCALE WITH THREE RANGES

ON THE 25A SCALE, READING IS 7.5 A

ON THE 5A SCALE, READING IS 1.5 A

ON THE 1A SCALE, READING IS 0.3 A

RESISTANCE

RESISTANCE IS OPPOSITION TO AN ELECTRIC CURRENT. When a certain voltage exists between two points in a piece of material the current between those points depends on the resistance of the material. If the resistance is high there will be a small current. MATERIALS WITH HIGH RESISTANCE ARE CALLED INSULATORS. If the resistance is low, there will be a large current. MATERIALS WITH LOW RESISTANCE ARE CALLED CONDUCTORS. If one volt causes a current of one ampere in a material, the material has a resistance of one ohm.

The resistance of a material depends upon three things.

1. The nature of the material-a material with many free electrons will have a low resistance.

2. The size of the material-cross-sectional area and length.

3. The temperature of the material-usually resistance increases as temperature increases.

SOME GOOD INSULATORS

GLASS
PLASTIC
RUBBER
PURE WATER

SOME GOOD CONDUCTORS

SILVER
COPPER
ALUMINUM
IRON
LEAD
SALT WATER

SOME SEMI-CONDUCTORS*

CARBON
GERMANIUM
COPPER OXIDE
SILICON

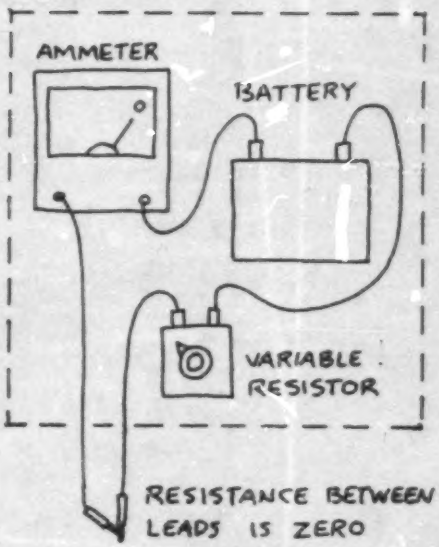
*A SEMICONDUCTOR IS A MATERIAL THAT CAN ACT AS EITHER A CONDUCTOR OR AN INSULATOR.

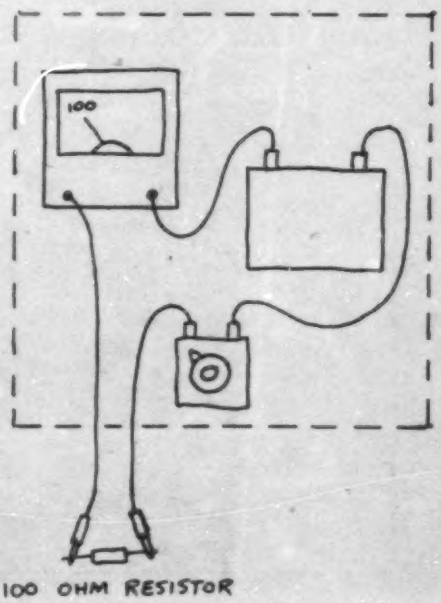
EXPERIMENT NO. 3

MEASURING RESISTANCE

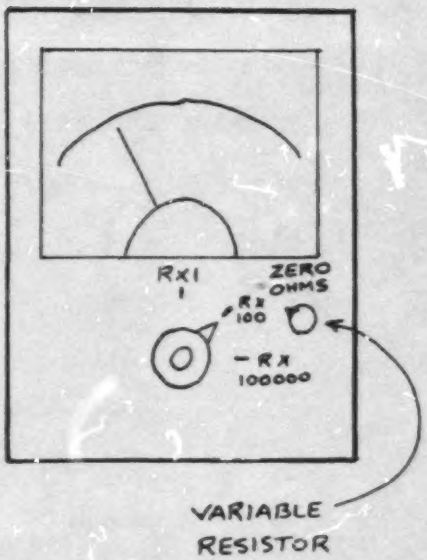
The purpose of this experiment is to introduce you to the ohmmeter and show you how to use it.

RESISTANCE IS MEASURED IN OHMS. THE DEVICE USED TO MEASURE IT IS CALLED AN OHMMETER. The ohmmeter is an ammeter, a battery, and a variable resistor connected together. When the ohmmeter leads are touched to gether (shorted), the battery causes a current in the variable resistor and the ammeter. With the leads shortened, the resistor is adjusted until the ammeter needle points to zero--which is the resistance between the ends of the leads. Now, if the leads are connected to a 100-ohm resistor the current will be reduced and the ammeter needle will point to 100. (When an ammeter is used in an ohmmeter the numbers on the scale are not in the normal order--zero is on the right).





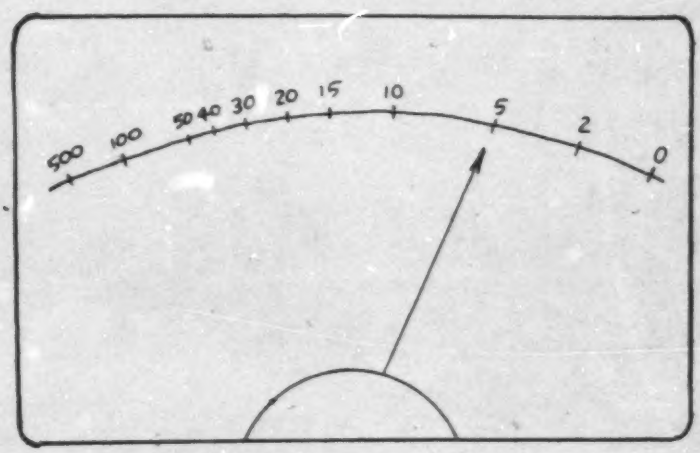
Ohmmeters are usually built into multimeters. When there are several resistance ranges the selector switch will have positions labelled RX1, RX100, RX100000, and so forth. On the RX1 range the resistance is read directly from the meter face numbers. On the RX100 range the numbers on the meter face must be multiplied by 100, and so forth.



When using an ohmmeter there are two rules to remember.

1. Disconnect the electricity from the device whose resistance is being measured.

2. Zero the meter when you start and each time you change ranges.



OHMMETER SCALE

ON Rx1 - 5 OHMS

ON Rx100 - 500 OHMS

ON Rx100000 - 500000 OHMS

Use an ohmmeter to take data as follows.

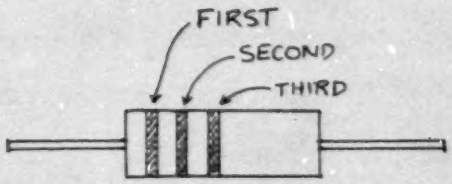
1. Measure the resistance of several electronic-type resistors (with color code). Make a list that indicates the resistance for each color combination.

2. Measure the resistance of several coils of copper wire of different cross-sectional areas (gauges)* and different lengths. Take enough data to determine how the gauge and length affect the resistance.

3. Compare the resistance of several types of metal of the same gauge and length. List the metals in order of increasing resistance.

4. Coil two feet of iron wire around a pencil, leaving a few inches straight at each end. Hook an ohmmeter to the coil and observe how the resistance changes as you heat the wire with a bunsen burner.

FILL OUT THE LABORATORY DATA SHEET



READ THE COLOR CODE STARTING WITH THE COLOR NEAREST ONE END.

*The gauge of a wire is an indicator of its cross-sectional area (or thickness). We use a system of gauge numbers called the American Wire Gauge (AWG). Larger gauge numbers indicate smaller wire as shown in the table below.

GAUGE	AREA (SQ. IN.)	RESISTANCE OF 1000 FT	
		COPPER	ALUM.
12	.00513	1.62	2.66
14	.00323	2.57	4.22
18	.00128	6.51	10.7
20	.00080	10.15	16.7
22	.00050	16.14	26.5
24	.00032	25.67	42.1
28	.00013	65.9	106
30	.00008	103.2	169

OHM'S LAW

Electric potential difference, electric current and resistance are all tied together by a relationship known as Ohm's Law. It says that current increases as voltage increases and current decreases as resistance increases. Or, more simply,

WHEN VOLTAGE GOES UP - CURRENT GOES UP (RESISTANCE CONSTANT),
WHEN RESISTANCE GOES UP - CURRENT GOES DOWN (VOLTAGE CONSTANT).

WHEN THERE IS ONE AMP IN A RESISTANCE OF ONE OHM, THERE WILL BE ONE VOLT ACROSS IT. This is often written as an equation.

$$\text{CURRENT} = \frac{\text{VOLTAGE}}{\text{RESISTANCE}}$$

Ohm's Law enables us to calculate either current, voltage, or resistance if we know the other two. The equation for voltage is

VOLTAGE = CURRENT X RESISTANCE

To find resistance, we use

$$\text{RESISTANCE} = \frac{\text{VOLTAGE}}{\text{CURRENT}}$$

Symbols are often used in working with voltage, current, and resistance.

Electrical Quantity	Symbol of Quantity	Unit of Quantity	Symbol of Unit
Potential difference (Voltage)	E	Volt	V
Current	I	Ampere (Amp)	A
Resistance	R	Ohm	Ω

Using symbols, Ohm's Law can be written as follows.

$$I = \frac{E}{R}, \quad E = I \times R, \quad \text{and} \quad R = \frac{E}{I}$$

How much current will there be in a wire with a resistance of 3 ohms when 12 volts is applied to it?

$$I = \frac{E}{R} = \frac{12V}{3\Omega} = 4A, \quad I = 4 \text{ amps}$$

How much voltage is required to push 12 amps through a resistance of 10 ohms?

$E = I \times R = 12A \times 10\Omega = 120V$, E = 120 volts

How much resistance does a light bulb have that carries 0.5 amps when 120 volts is applied?

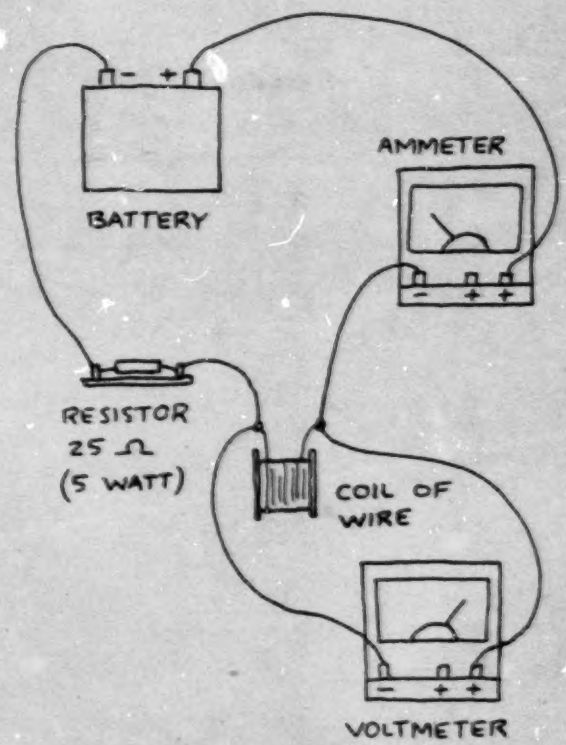
$$R = \frac{E}{I} = \frac{120V}{0.5A} = 240\Omega, \quad R = 240 \text{ ohms}$$

EXPERIMENT NO. 4

OHM'S LAW

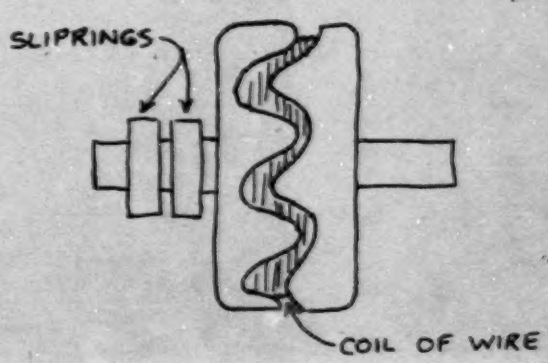
The purpose of this experiment is to give you some additional experience using electrical meters and Ohm's Law.

Use a battery (or power supply), a resistor, a voltmeter, and an ammeter to measure the resistance of the same coils of wire that you used in Experiment No. 3. Hook each coil of wire into the circuit and measure the current in the coil and the voltage across it. Then use Ohm's Law to find the resistance. Do this for several different voltages. Record all your data and your calculations.



Use the same method to find the resistance of the field coil of an alternator. The two sliprings are the ends of the wire. Estimate the gauge of the wire used in the field coil. Knowing the resistance of the field coil and the resistance (and length) of some shorter coils of the same gauge, estimate the length of the wire in the field coil.

FILL OUT THE LABORATORY DATA SHEET



FIELD COIL OF ALTERNATOR

LABORATORY DATA SHEET

Sheet 1

UNIT I. EXPERIMENTS 1,2,3 AND 4

Name _____
Date _____

EXPERIMENT NO. 1

MEASURING ELECTRIC POTENTIAL DIFFERENCE

Description of Battery	Voltage Measured		
	Voltmeter No. 1	Voltmeter No. 2	Voltmeter No. 3

EXPERIMENT NO. 2

MEASURING ELECTRIC CURRENT

Description of Resistor	Current Measured		
	Ammeter No. 1	Ammeter No. 2	Ammeter No. 3

EXPERIMENT NO. 3

MEASURING RESISTANCE

Color Code	Resistance

LABORATORY DATA SHEET

UNIT I

EXPERIMENT NO. 3 - CONTINUED

Gauge	Length	Resistance

List Metals (with best conductor at top)

_____

_____

_____

_____

_____

Describe how the resistance of iron wire changed as you heated it.

_____

EXPERIMENT NO. 4

OHM'S LAW

	Coil			
Gauge	Length	Voltage	Current	Resistance
Field Coil				

Put your calculations using Ohm's Law on the back of this sheet or on another sheet and attach it to this sheet.

Estimated gauge of field coil wire _____.

Estimated length of field coil wire _____.

UNIT I. AUDIO VISUAL MATERIALS

Use the audio-visual materials and then answer the questions below.

1. "Current Electricity", a slide-sound program
2. "Electricity in Motion", a 16 mm film.

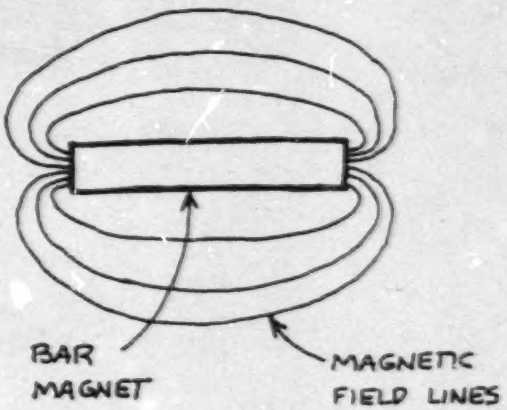
UNIT I. REVIEW QUESTIONS

1. What is electric current?
2. What is electric potential?
3. What is a battery? What does it do to electrons?
4. What is electrical resistance?
5. Put Ohm's Law into your own words.
6. How much current will there be in a 5-ohm resistor with 60 volts across it?_____
7. How much voltage will there be across a 20-ohm resistor with 3 amps in it?_____
8. How much resistance is necessary to limit the current to 2 amps when the voltage is 60 volts?_____

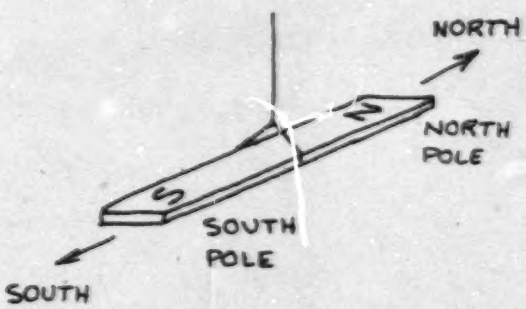
UNIT II. MAGNETS FROM ELECTRICITY

Just as charged bodies are surrounded by electric fields, magnetic bodies are surrounded by magnetic fields. Electric fields and magnetic fields appear to be different but they are related in some interesting ways.

MAGNETIC FIELDS



MAGNETIC BODIES (MAGNETS) ARE SURROUNDED BY INVISIBLE MAGNETIC FIELDS. The magnetic field can be imagined as lines that leave the magnet at one point and enter the magnet at another point. The points where these invisible lines leave and enter the magnet are called poles. If a bar-shaped magnet is free to move in any direction, it will come to rest with one of its ends pointing north. We call this end the north pole of the magnet. The other end points south and is called the south pole of the magnet.



A magnet that is free to move is a compass. Its north pole is attracted to the earth's magnetic south pole (located in northern Canada). THE FIELD AROUND A MAGNET EXERTS FORCES ON OTHER MAGNETS.

A COMPASS IS A MAGNET THAT IS FREE TO MOVE

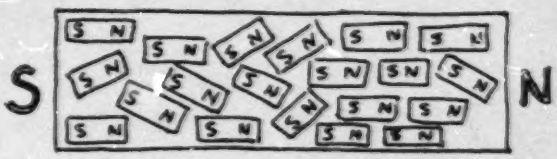
The north pole of a magnet will attract the south pole of another magnet but will repel another north pole. A south pole will attract a north pole but repel another south pole. Magnetic fields can cause certain materials to become magnetized and then attract them.

OPPOSITE POLES ATTRACT

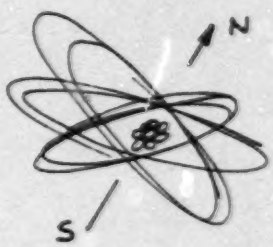
LIKE POLES REPEL

PERMANENT MAGNETS

A permanent magnet is a material surrounded by an unchanging magnetic field. Only a few materials can be permanent magnets. The most common are the alloys of iron, nickel, and cobalt. These particular materials are magnetic because their atoms are magnetic. Atoms act as small magnets when most of their electrically charged electrons spin in the same direction. THE MOVING ELECTRIC CHARGE IS THE CAUSE OF ALL MAGNETIC FIELDS.

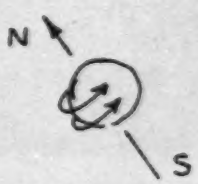


PERMANENT MAGNETS HAVE MAGNETIC ATOMS POINTING IN THE SAME DIRECTION.



CERTAIN ATOMS HAVE MAGNETIC PROPERTIES.

Permanent magnets are made when a magnet field causes the atoms to line up with their north poles in the same direction. Permanent magnets can be destroyed by jumbling up the atoms again.



THE SMALLEST MAGNET IS THE SPINNING ELECTRON.

EXPERIMENT NO. 5

THE MAGNETIC FIELD AROUND A PERMANENT MAGNET

The purpose of this experiment is to examine the shape and the strength of the fields around several magnets.

The effect that a magnetic field has on iron filings can be used to create a "map" of the field. Under the influence of a magnetic field, each particle of iron becomes a tiny magnet. As a magnet, it is attracted to the magnet that created the field. When the field is taken away the particles will lose their magnetic properties.

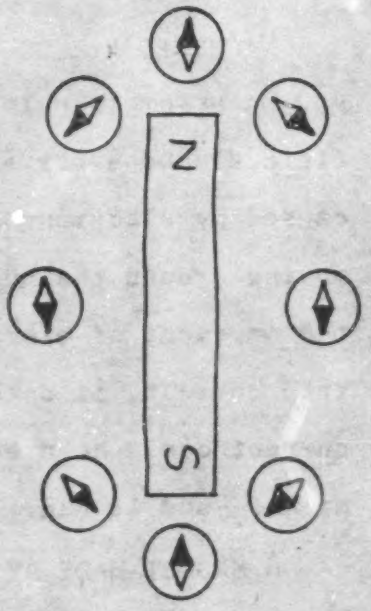
Lay a bar magnet on a piece of paper or cardboard and sprinkle iron filings over and around it. When you tap the paper with your finger, the filings will line up in the magnetic field. Draw a sketch of the result. Where is the field strongest? Where is it weakest?

Do the same thing for a horse-shoeshaped magnet. Where is the magnetic field strongest?

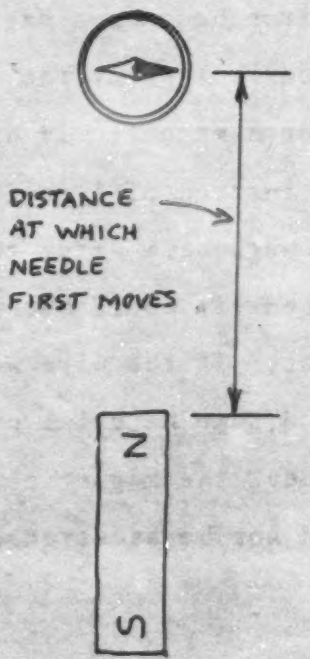
A compass can also be used to detect a magnetic field. As a compass is brought into a magnetic field its north pole will point towards the south pole of the magnet which causes the field. The distance at which a magnet can cause a compass needle to move can be used to compare the strengths of different magnets.

Measure the relative strength of several bar magnets as follows. Put a small compass several feet from a magnet and let the needle come to rest. Approach the compass from the east or the west with one end of a bar magnet. Record the distance at which the magnet first causes the needle to move.

FILL OUT THE LABORATORY DATA SHEET



USING A COMPASS TO "MAP" A MAGNETIC FIELD

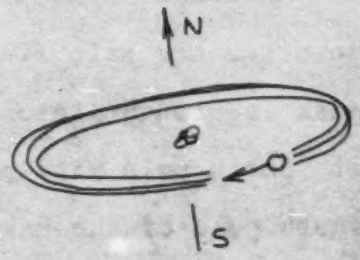


MEASURING THE STRENGTH OF A MAGNET

ELECTROMAGNETS

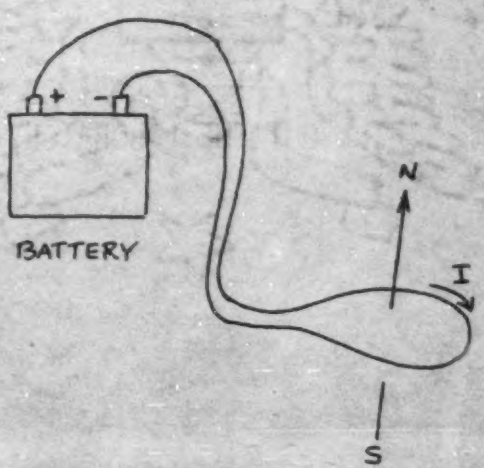
MAGNETIC FIELDS ARE CAUSED BY MOVING ELECTRIC CHARGES. The magnetic field around a permanent magnet is caused by electrons spinning and moving around the nucleus. Since the movement of electrons is an electric current, it seems that electric current could be used to make a magnet--and it can.

A MAGNET MADE BY AN ELECTRIC CURRENT IN A WIRE IS CALLED AN ELECTROMAGNET. When a wire is wrapped around a piece of soft iron and current passed through the wire, the iron becomes a magnet. When the current stops the iron is no longer a magnet. If hard steel were used instead of iron it would retain some magnetism after the current stopped--it would become a permanent magnet. If the wire were wrapped around some material other than iron or steel the magnetic field produced would not be as strong.



THE ELECTRON MOVING AROUND THE NUCLEUS CAUSES SOME MATERIALS TO BE MAGNETIC...

... BUT MOST PERMANENT MAGNETS ARE DUE TO THE ELECTRON SPINNING AS IT MOVES ALONG.



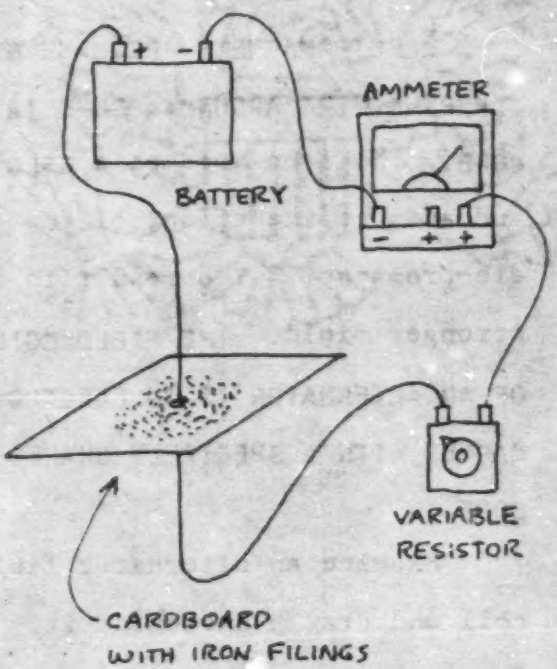
CURRENT IN A WIRE WILL PRODUCE A MAGNETIC FIELD.

EXPERIMENT NO. 6

THE MAGNETIC FIELD AROUND A CURRENT-CARRYING WIRE

The purpose of this experiment is to examine the shape of a magnetic field caused by an electric current and to determine the factors that affect its strength.

Use iron filings to "map" the magnetic field around a straight section of current-carrying wire. Hook the wire to a battery, an ammeter, and a variable resistor. Then pass it through a small hole in a piece of cardboard. Send a current of 10 amperes through the wire and sprinkle iron filings on the cardboard around the wire. Tap the cardboard lightly and sketch the pattern that appears.



Place a compass next to the wire so that the north pole of the compass points to the wire. Slowly increase the current in the wire from 0 to 10 amperes and back. Decribe the action of the compass.

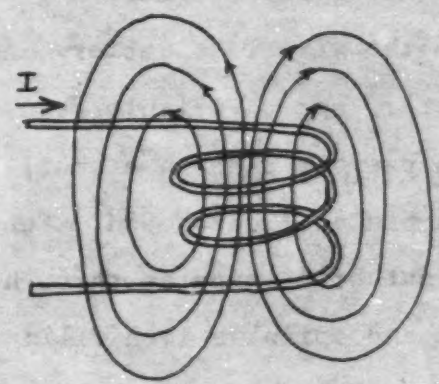
When a current-carrying wire is wound into a coil the magnetic fields around adjacent sections of wire add together. The result is a stronger magnetic field. If the number of turns of wire is increased, the field gets stronger.

ELECTROMAGNETS ARE MADE BY WRAPPING WIRE AROUND A SOFT IRON CORE. The iron becomes a magnet and adds to the effect of the electromagnet. The result is a stronger field. THE FIELD COIL OF AN ALTERNATOR IS AN ELECTRO-MAGNET WITH A SPECIALLY SHAPED IRON CORE.

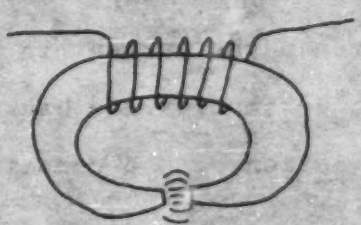
Examine an alternator field coil and draw a sketch of it. Label the windings and the iron core.

Pass currents of 0.5A, 1.0A, 1.5A and 2.0A through the field coil and record the distances at which the magnetic field generated causes a compass needle to move. Connect the positive side of the power supply or battery to the end slipring on the field coil.

THE MAGNETIC FIELD AROUND A STRAIGHT CURRENT-CARRYING WIRE.



THE MAGNETIC FIELD AROUND A COIL OF WIRE IS LIKE THE FIELD AROUND A BAR MAGNET.



AN IRON CORE CAN BE USED TO INCREASE THE STRENGTH OF A MAGNETIC FIELD.

UNIT II. LABORATORY DATA SHEET

Sheet 1

EXPERIMENTS NO. 5 AND 6

Name_____

Date_____

EXPERIMENT NO. 5

THE MAGNETIC FIELD AROUND A PERMANENT MAGNET

Sketch the arrangement of iron filings around a bar magnet and a horseshoe magnet.

Description of Bar Magnet	Distance at which compass first moves

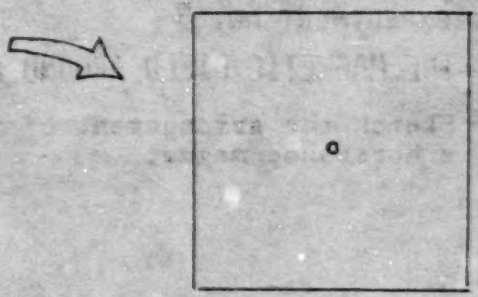
Which magnet is strongest?_____

UNIT II. LABORATORY DATA SHEET Sheet 2

EXPERIMENT NO. 6

THE MAGNETIC FIELD AROUND A CURRENT-CARRYING WIRE

Sketch the arrangement of the iron filings around a current-carrying wire. The wire is going down through the center of the square



Describe the action of the compass as the current is increased and decreased.

How does the amount of current affect the strength of the field?

Current in field coil	Distance at which compass first moves
0	
.5A	
1.0A	
1.5A	
2.0A	

Sketch the alternator field coil and label its parts.

UNIT II. AUDIO-VISUAL MATERIALS

Use the audio-visual materials and then answer the questions below.

1. "Magnets from Electricity", a sound/slide program.
2. "Magnetism and Electricity", a 16 mm film.

UNIT II. REVIEW QUESTIONS

1. What is a permanent magnet?
2. What materials can be magnetized?
3. What is the cause of all magnetic fields?
4. What is an electromagnet?
5. Why is an electromagnet stronger with an iron core?
6. How does amount of current affect the strength of an electromagnet?

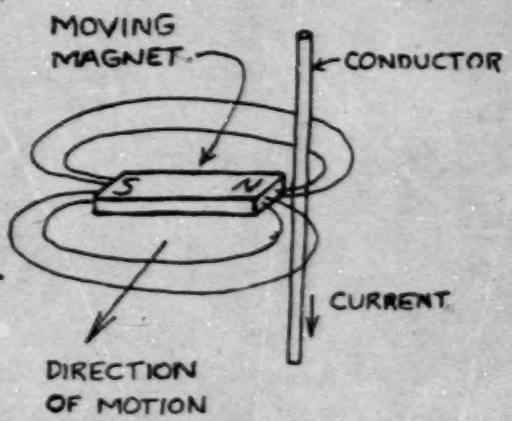
UNIT III, ELECTRICITY FROM MAGNETS

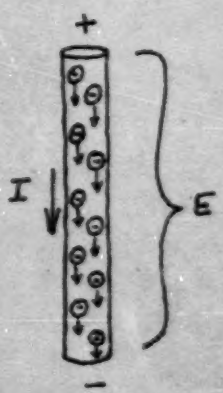
Magnetic fields are created by moving charges. The relationship between electricity and magnetism goes further. A moving magnetic field can cause an electric current. This fact is the basis for the operation of the automotive alternator and essentially all the electrical energy produced in the world today.

GENERATORS

WHEN A MAGNETIC FIELD MOVES PAST A CONDUCTOR--OR A CONDUCTOR MOVES THROUGH A MAGNETIC FIELD--ELECTRONS WILL FLOW IN THE CONDUCTOR. A current generated in this manner is called an induced current. If the ends of the conductor are not connected to anything, the electron flow will cause one end to be negative and the other positive. There will be a voltage--an induced voltage--across the ends of the wire. This is called the generator terminal voltage.

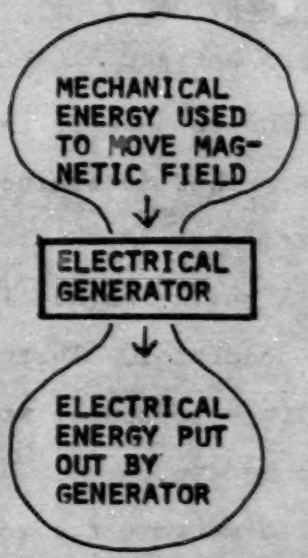
If the terminals of the generator are connected to a device that uses electricity, such as a light bulb, the terminal voltage will cause a current in that device. The generator and the electrical load will have the same current.

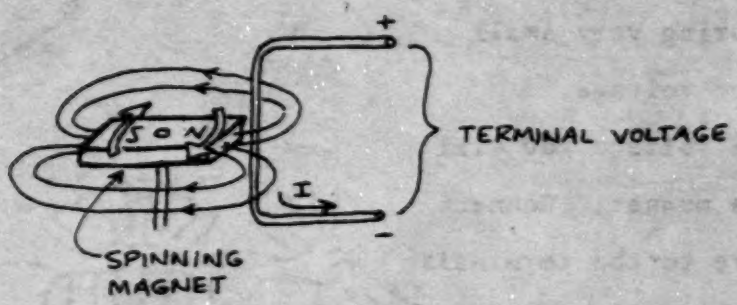




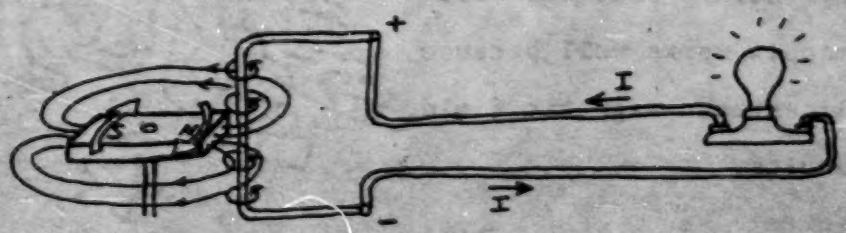
WHEN A MOVING MAGNET CAUSES A CURRENT — THI CURRENT CAUSES A VOLTA TO APPEAR ACROSS THE E OF THE CONDUCTOR.

The current in the conductor will produce its own magnetic field. Inside the generator this magnetic field will oppose the field of the moving magnet. When an electrical load is connected to the generator a current is induced which makes it harder for the magnet to move inside the generator. THE MECHANICAL ENERGY OF THE MOVING MAGNET IS BEING CHANGED TO ELECTRICAL ENERGY BY THE GENERATOR.





CURRENT INSIDE THE GENERATOR CAUSES THE TERMINAL VOLTAGE TO APPEAR. IF NO LOAD IS CONNECTED TO THE GENERATOR THE CURRENT WILL BE SMALL AND THE MAGNET WILL BE EASY TO TURN.



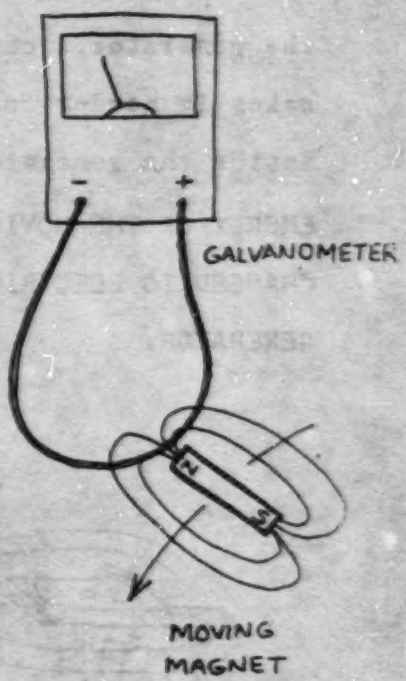
IF THE GENERATOR IS CONNECTED TO A LOAD, THE TERMINAL VOLTAGE WILL CAUSE A LARGE CURRENT. THE MAGNETIC FIELD CAUSED BY THE LOAD CURRENT WILL MAKE IT HARD TO TURN THE MAGNET.

EXPERIMENT NO. 7

INDUCED VOLTAGE

The purpose of this experiment is to introduce you to the factors that determine the amount of voltage generated by a moving magnet.

A moving magnet induces a current in a conductor. That current causes a voltage to appear at the ends of the conductor.



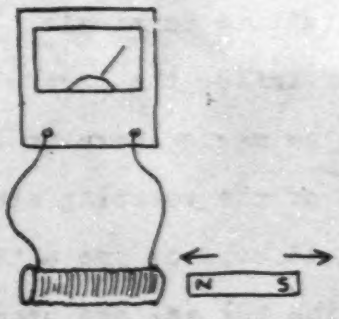
To measure the voltage generated you will need a very sensitive voltmeter--a millivolt meter--or a galvanometer. A galvanometer is an electric meter used for measuring very small amounts of current or voltage.

To generate the voltage you will need some wire and a magnet. Connect a short piece of wire to the terminals of the meter. Move a bar magnet past the wire. Record the results. Move a stronger magnet past the wire--a horseshoe magnet works well because it has a small, strong magnetic field. Record the results.

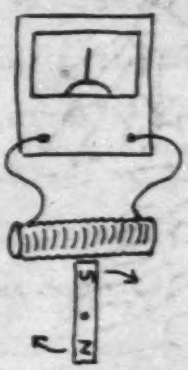
Next connect the meter to a coil of wire. If one is not available, make your own by winding about 200 turns of small wire onto a one-inch-diameter tube. Push the bar magnet into the coil slowly and pull it out again. Describe what happened. Push it in and pull it out again using a quick motion. How did the voltage generated vary?

Observe the effect of a rotating magnet by spinning a bar magnet while holding the coil of wire near it. Describe the variation of the voltage produced.

IN THE ALTERNATOR THE VOLTAGE IS INDUCED IN A COIL OF WIRE CALLED THE ARMATURE. It is wound on an iron core to produce a stronger magnetic field as the poles pass by the wire. The armature is wound with three pieces of wire that are connected together at one end. A voltage is produced between each of the free ends. So there are actually three voltages--all the same. THE ARMATURE IS A STATIONARY COIL OF WIRE AND IS ALSO CALLED THE STATOR.

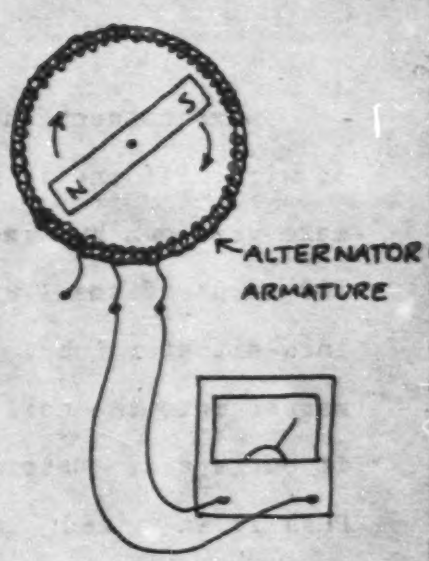


MOVE THE MAGNET IN AND OUT OF THE COIL OF WIRE.



ROTATE THE MAGNET NEAR THE COIL OF WIRE.

Connect the meter to the armature coil of an alternator--use any two of the armature terminals. Center the magnet inside the armature and spin it. The magnet here is taking the place of the rotating electromagnet or field coil of the alternator. Describe the voltage produced. Use two different terminals and repeat the test. How does the speed of rotation affect the voltage produced?

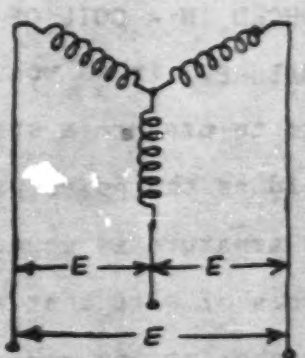


MEASURING THE VOLTAGE PRODUCED BY A PERMANENT MAGNET ROTATING INSIDE AN ALTERNATOR ARMATURE.

In summary, the amount of voltage produced by a moving magnetic field is determined by the following.

1. Magnetic field strength--stronger magnets produce higher voltage.
2. Length of conductor in magnetic field--using a coil of wire instead of a straight length results in higher voltage.
3. Speed of magnetic field--the faster the magnet moves, the higher the voltage.

FILL OUT THE LABORATORY DATA SHEET



THE THREE WINDINGS IN AN ALTERNATOR ARMATURE GENERATE THREE EQUAL VOLTAGES.

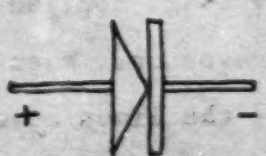
AC AND DC

A. C. STANDS FOR ALTERNATING CURRENT AND D.C. STANDS FOR DIRECT CURRENT. An alternating current changes direction at regular intervals of time. A direct current does not change direction.

Until the early 1960's automobiles used direct current generators. The switch to alternating current generators--or alternators-- was due to increased demands for electrical power at slow engine speeds. Before the electrical energy produced by the alternator can be used in an automobile, it must be changed from a.c. to d.c. This is done by diodes.

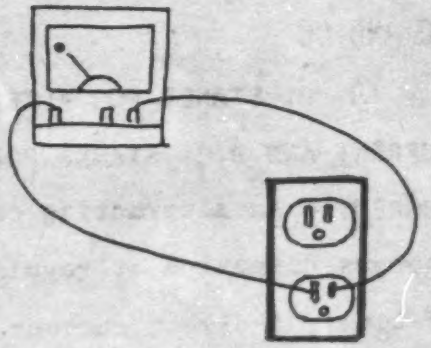
A DIODE IS A DEVICE THAT WILL CONDUCT ELECTRIC CURRENT IN ONE DIRECTION ONLY. When an alternating voltage is applied to a diode, electrons are allowed to pass in one direction but prevented from passing in the other direction. The six diodes mounted on the frame of the alternator change the a.c. output of the alternator to d.c.

A DIODE HAS A POSITIVE END AND A NEGATIVE END.



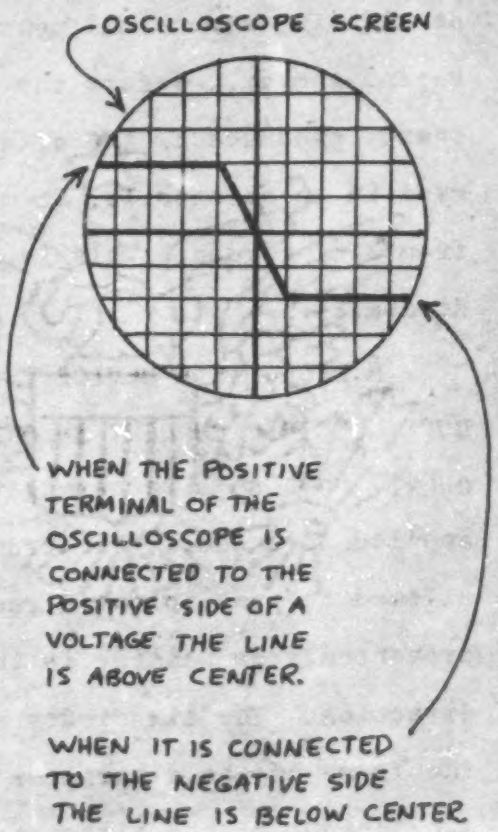
ELECTRICAL SYMBOL FOR DIODE — ELECTRON FLOW MUST BE FROM NEGATIVE TO POSITIVE.

When alternating current (or an alternating voltage) is applied to a meter the needle will move back and forth as the direction of current (or polarity) changes. If the rate at which the current changes direction is too fast the needle will not have time to respond and will not move at all. To measure alternating current or voltage we must use special meters with diodes.



A D.C. VOLTMETER WOULD INDICATE ZERO WHEN CONNECTED TO AN A.C. RECEPTACLE.

Another device used to measure alternating voltage and to observe how it changes polarity is the oscilloscope. An oscilloscope uses an electron beam, rather than a needle, to indicate amount of voltage. The oscilloscope is similar to a television. As the electron beam moves across the face it makes a bright line. When the voltage applied is increased--the line moves up. When the voltage decreases--the lines moves down. The rate at which the beam moves across the face can be controlled. Since the electron beam does not weigh as much as the needle in a meter it can respond to alternating voltages.


OSCILLOSCOPE SCREEN
WHEN THE POSITIVE TERMINAL OF THE OSCILLOSCOPE IS CONNECTED TO THE POSITIVE SIDE OF A VOLTAGE THE LINE IS ABOVE CENTER.
WHEN IT IS CONNECTED TO THE NEGATIVE SIDE THE LINE IS BELOW CENTER

EXPERIMENT NO. 8

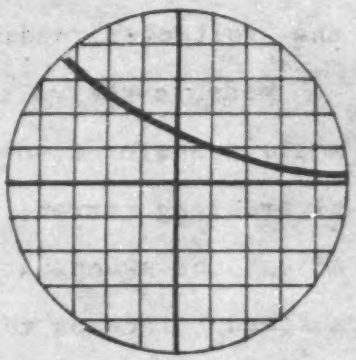
ALTERNATING CURRENT

The purpose of this experiment is to introduce you to the oscilloscope and show you how it is used to study alternating currents (and voltages).

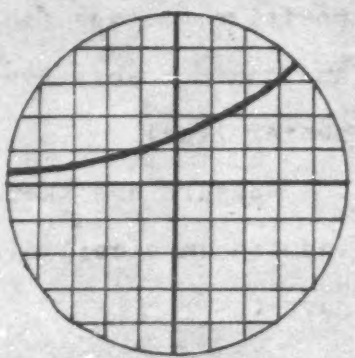
The oscilloscope is used for measuring voltage. It will show you how a voltage changes with respect to time--it draws a graph. If the voltage applied to the terminals of an oscilloscope is a steady voltage it will show a straight line across the screen. The vertical position of the line indicates the amount of voltage. If the voltage applied varies (such as alternating voltage) the line will move up and down as it goes across the screen.

Use the oscilloscope to measure the voltages of several batteries as follows:

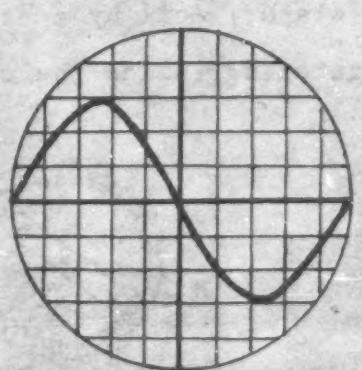
1. Turn the oscilloscope on.
2. Select a voltage range (given in volts per inch or volts per cm) such that a deflection from the center of the screen to the top represents a voltage higher than the battery voltage.
3. Select a sweep rate that gives you a solid line.
4. Center the line (trace) on the screen.
5. Connect the leads to a battery and determine the voltage represented by the height of the line.



THE VOLTAGE BEING MEASURED IS DECREASING.



THE VOLTAGE BEING MEASURED IS INCREASING.



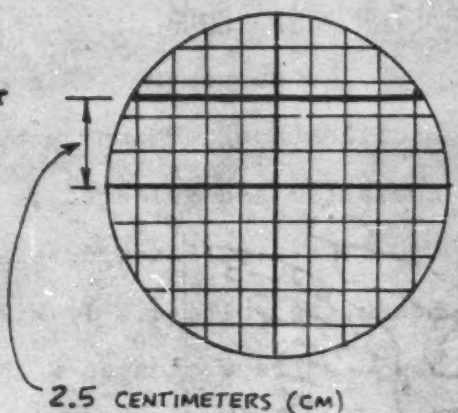
THE VOLTAGE BEING MEASURED IS ALTERNATING BETWEEN POSITIVE AND NEGATIVE.

Make a table that lists the voltages you measure with the oscilloscope. Check your measurements with a voltmeter and list the voltmeter readings.

Measure the voltage output of a small transformer-6 or 12 volt- or an alternating current power supply. Adjust the sweep rate until you get a steady trace on the screen. Sketch a picture of what you see on the oscilloscope and indicate the maximum positive voltage (above the center line) and maximum negative voltage (below the center line).

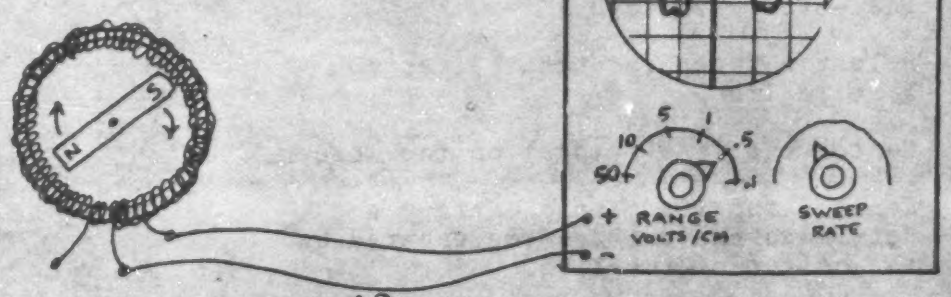
Measure and sketch the voltage induced in a coil of wire by a rotating magnet.

Measure and sketch the voltage induced in the alternator armature (stator) coil by a permanent magnet rotating inside the coil.

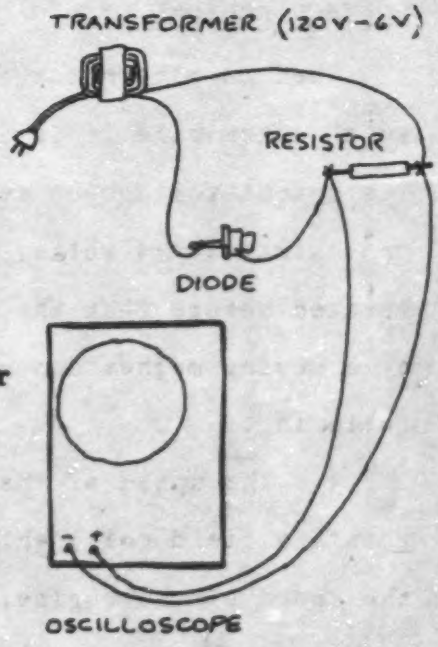


RANGE SETTING	VOLTAGE
0.1 VOLTS/CM	0.25 V
0.5 VOLTS/CM	1.25 V
⋮	⋮
10 VOLTS/CM	25 V
50 VOLTS/CM	125 V

TO MEASURE A VOLTAGE WITH THE OSCILLOSCOPE, MULTIPLY THE HEIGHT OF THE LINE BY THE RANGE SETTING.

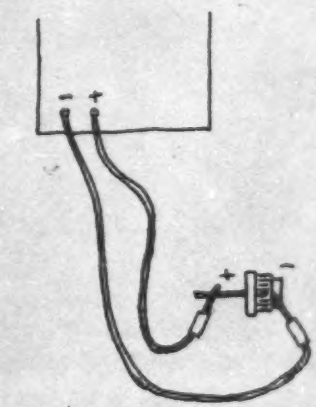


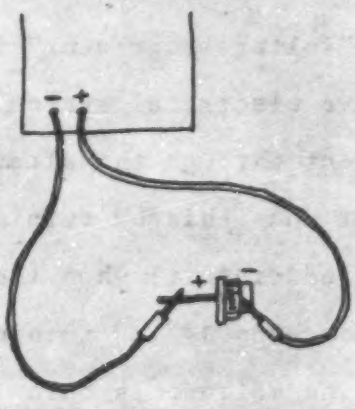
Set up the following circuit to see the effect of a diode on alternating current. Connect a 100 ohm resistor to a 6 or 12 volt transformer (or a.c. power supply) and observe the voltage across the resistor with an oscilloscope. Now connect a diode between the transformer and resistor. Sketch the voltage across the resistor. Turn the diode around and sketch the new trace that appears on the oscilloscope.



An ohmmeter can be used to determine if a diode is operating properly. The resistance of the diode should be low when the positive lead of the ohmmeter is connected to the positive side of the diode. It should be high when the ohmmeter positive is connected to the diode negative.

Use an ohmmeter to check some alternator diodes (disconnected from the alterantors) and record the resistance in both directions.





VOLTAGE CONTROL

When an alternator is operating in an automobile it is important that its output voltage be regulated to approximately 14 volts. You demonstrated before that the voltage induced by a moving magnet depends upon the following.

1. The speed of the magnet(the rotating field coil) which depends on the speed of the engine. It cannot be adjusted to control voltage.

2. The length of the wire(the stationary armature windings, which is fixed when the alternator is made. It cannot be easily changed.

3. The strength of the magnet (actually an electromagnet), which can be changed by changing the amount of current flowing through it.

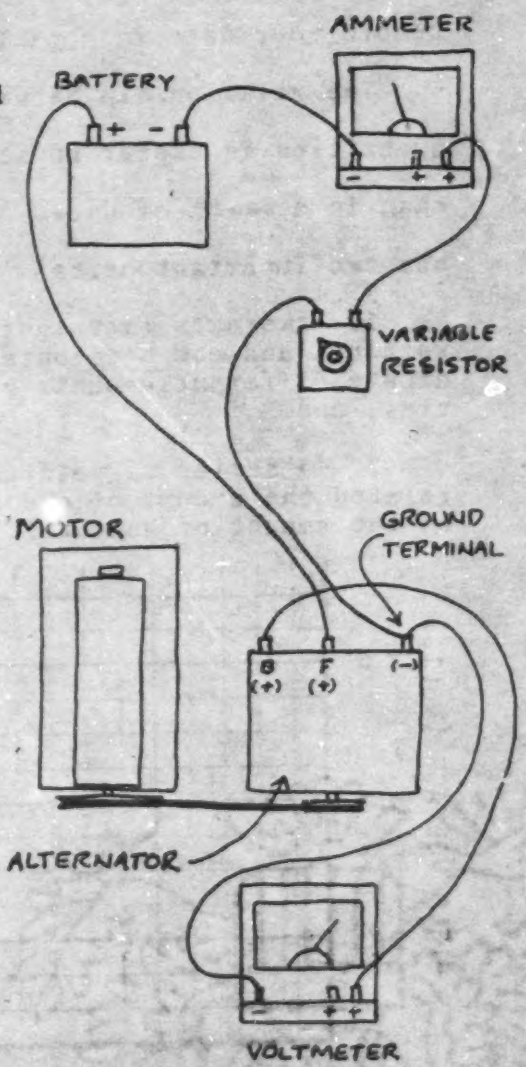
The "voltage regulator" in an automotive electrical system controls the current through the alternator field coil. It does this by turning the field off (or reducing it) when the output voltage exceeds 14 and turning it back on when the voltage is below 14. It does this many times per second.

EXPERIMENT NO. 9

CONTROLLING ALTERNATOR VOLTAGE

The purpose of this experiment is for you to determine how speed and field current affect the output voltage of an alternator. You will also learn how to describe the relationships by means of a graph.

In this experiment you will use an alternator driven by a variable-speed motor. The field current will be supplied by a 6 or 12 volt battery (or d.c. power supply) with a variable resistor to control the current and an ammeter to measure the current. The voltage output of the alternator will be measured with a d.c. voltmeter.



First determine how the speed of rotation affects the voltage. Turn on the drive motor and set it at its lowest speed. Apply a field current of 0.3 amps to the field coil and watch to make sure it says constant. Measure the speed with a tachmometer and the output voltage with a voltmeter. Take voltage readings at 500 r.p.m. intervals up to 2500 r.p.m. Record your data in a table.

Next take data to determine how the amount of field current affects the voltage. Drive the alternator at 1,000 r.p.m. and hold the speed constant. Measure the output voltage as the field current is varied from 0 to 1 amp in steps of 0.1 amps. Record your data in a table.

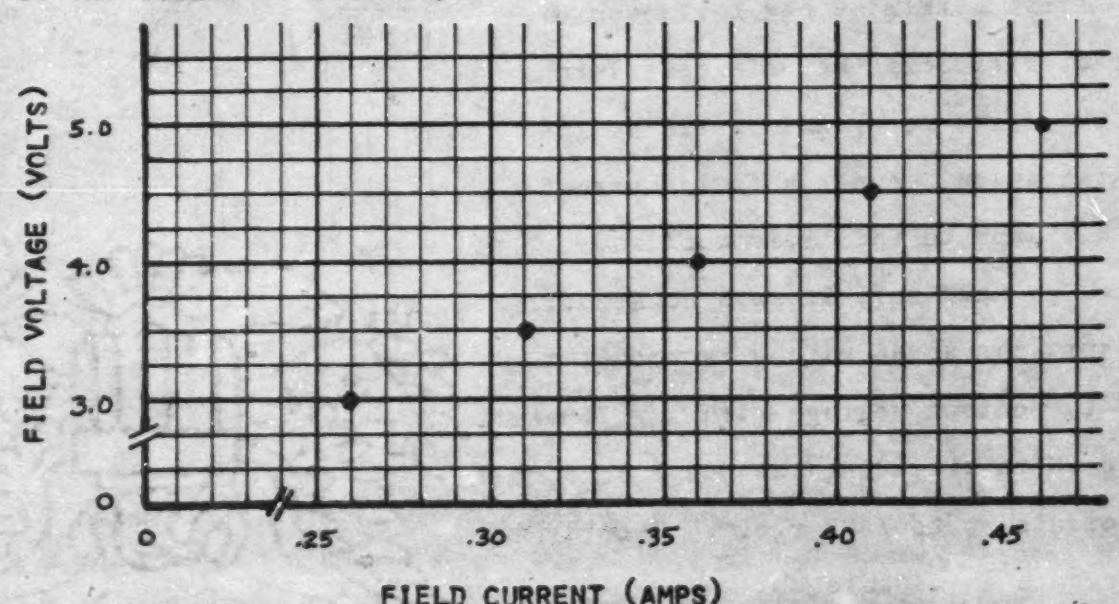
VOLTAGE APPLIED TO FIELD WINDINGS	CURRENT IN FIELD WINDINGS
3.0	0.26 A
3.5	0.31 A
4.0	0.36 A
4.5	0.41 A
5.0	0.46 A

The relationship between two quantities is easier to see in a graph than in a table of data. A graph has two important parts:

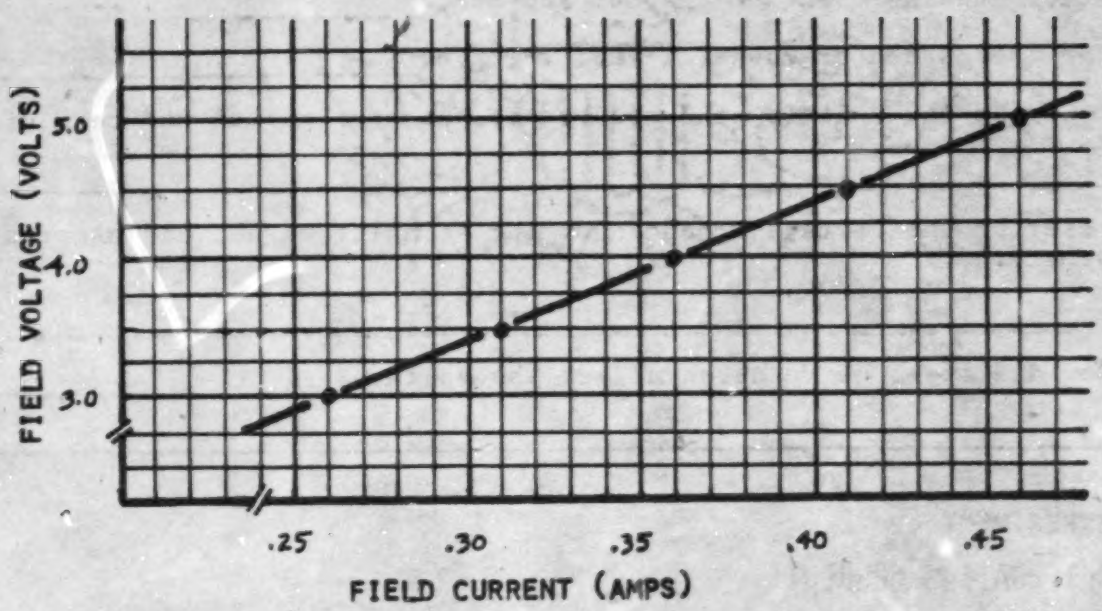
1. two axes (straight lines)-- one vertical and one horizontal that indicate different amounts of two quantities, and

2. a series of points that related the amount of one quantity to the amount of another.

FROM A TABLE OF DATA TO POINTS ON A GRAPH



After transferring the data from a table to a graph you can "guess" where other points would be by drawing a smooth line through the existing points. The smooth line enables you to see the general trend of the relationship and to read data that you did not take in your experiment.



Draw graphs of the data you took for output voltage vs. speed and output voltage vs. field current. How do speed and field current affect the voltage of an alternator?

UNIT III. LABORATORY DATA SHEET

Sheet 1

EXPERIMENTS NO. 7, 8, AND 9

Name _____

Date _____

EXPERIMENT NO. 7

INDUCED VOLTAGE

Meter reading using bar magnet. _____

Meter reading using stronger magnet. _____

Meter reading using bar magnet and coil. _____

How does speed of magnet affect voltage? _____

Describe the voltage produced by the spinning magnet and coil of wire.

_____

Describe the voltage produced by the spinning magnet and alternator armature.

_____

How did speed of rotation affect the voltage? _____

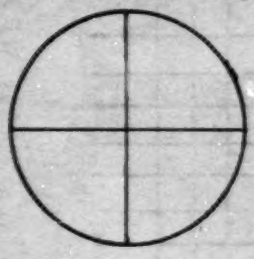
_____

EXPERIMENT NO- 8

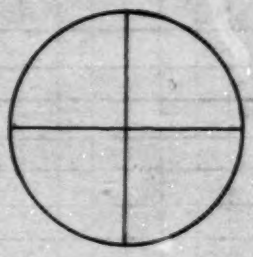
ALTERNATING CURRENT

Description of Battery	Voltage Measured with Oscilloscope	Voltage Measured with Voltmeter

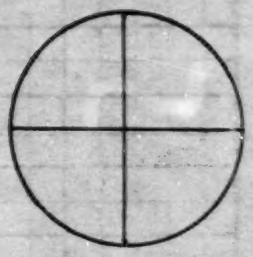
EXPERIMENT NO. 8 - Continued



VOLTAGE ACROSS RESISTOR WITHOUT DIODE



VOLTAGE ACROSS RESISTOR WITH DIODE



VOLTAGE ACROSS RESISTOR WITH DIODE REVERSED

Diode No.	Resistance in one direction	Resistance in other direction

EXPERIMENT NO. 9

CONTROLLING ALTERNATOR VOLTAGE

Speed (rpm)	Output Voltage (Volts)
500	
1000	
1500	
2000	
2500	

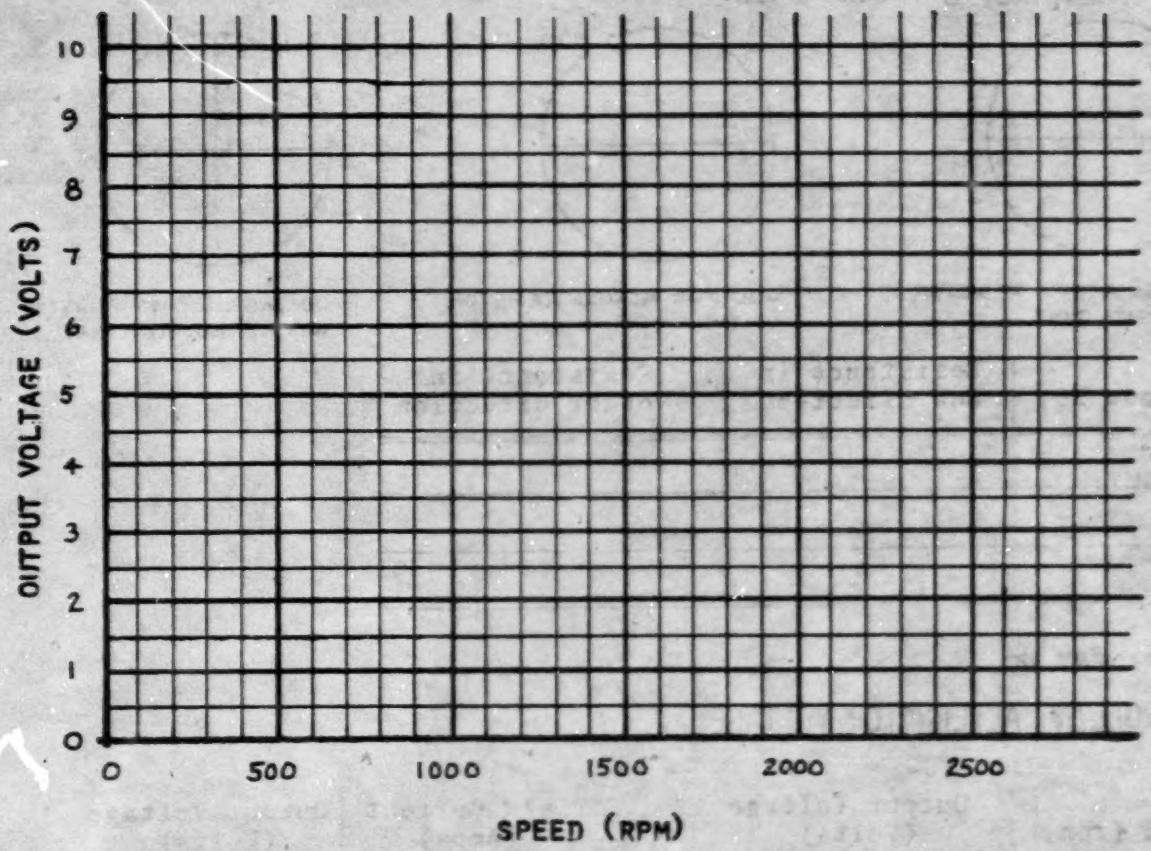
Graph your data on the following sheet.

Field Current (Amps)	Output Voltage (Volts)
0	
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	
0.8	
0.9	
1.0	

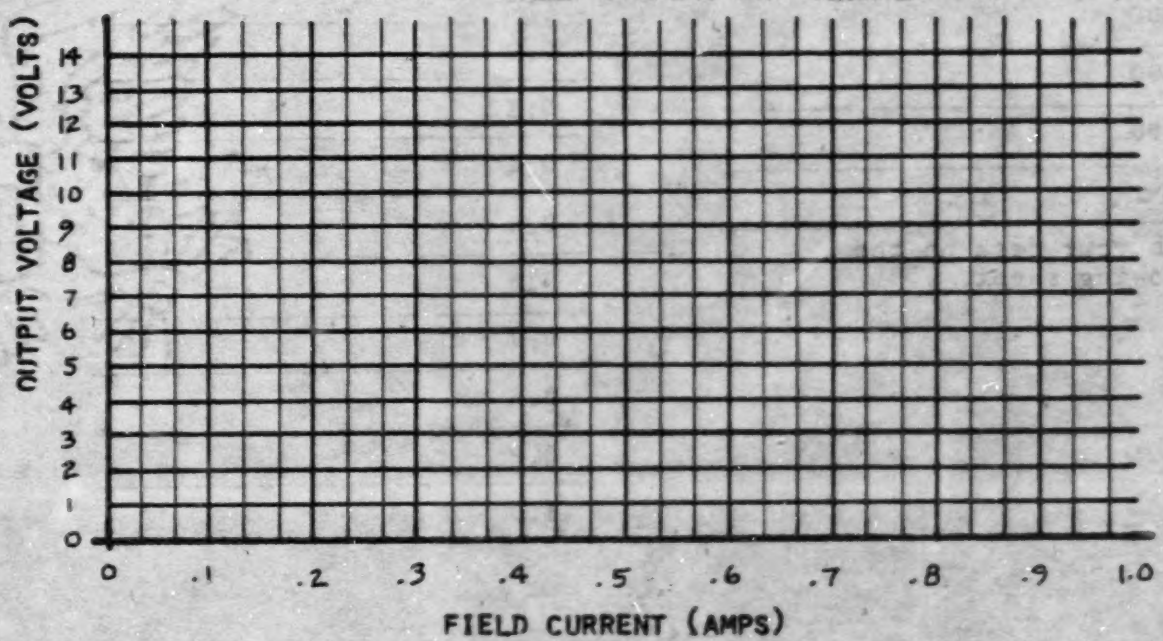
UNIT III LABORATORY DATA SHEET

SHEET 3

EFFECT OF SPEED ON VOLTAGE



EFFECT OF FIELD CURRENT ON VOLTAGE



UNIT III. AUDIO-VISUAL MATERIALS

Use the following audio-visual materials and answer the questions below.

1. "Electricity From Magnets", a sound/slide program.
2. "Electromagnetic Induction", a 16 mm film.

UNIT III. REVIEW QUESTIONS

1. Under what conditions can a magnetic field cause electrons to flow?
2. What factors control the size of an induced voltage?
3. In what part of the alternator is a voltage induced?
4. What is the purpose of the diodes in an alternator?
5. What is the difference between a.c. and d.c.?
6. How does the speed of rotation of an alternator affect the output voltage?
7. How does the amount of field current in an alternator affect the output voltage?

UNIT IV. ENERGY CONVERSION

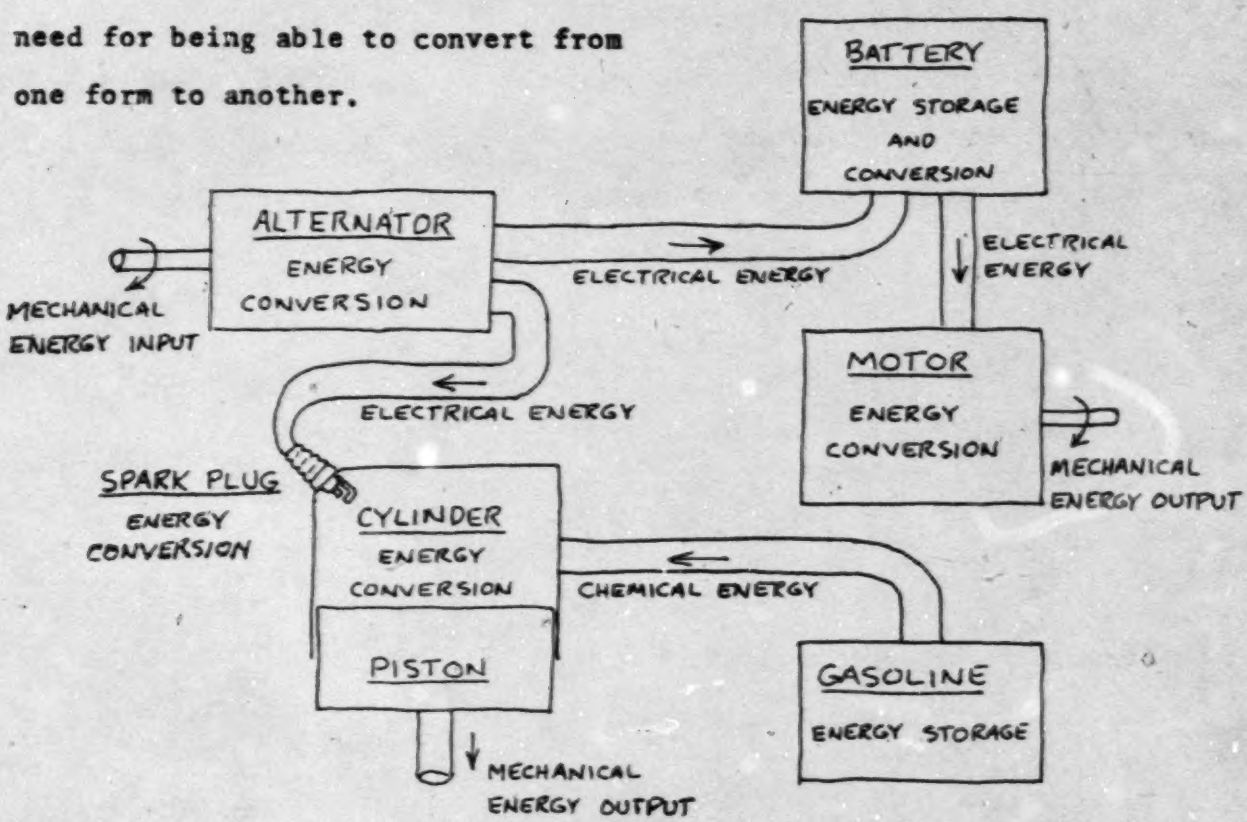
The alternator is an energy conversion device. It converts part of the mechanical energy of a rotating crankshaft into electrical energy. A look at the energy conversions associated with the alternator will give you a better understanding of the very important concept of energy.

ENERGY AND POWER

ENERGY IS NEVER USED UP, IT IS SIMPLY CONVERTED FROM ONE FORM TO ANOTHER. Some of the forms of energy found in the automobile are listed below.

1. Chemical energy - stored in the gasoline and the storage battery.
2. Thermal energy (also called heat energy) - used to expand the gases that move the piston.
3. Mechanical energy - found in the rotation of some parts and the motion of the automobile.
4. Electrical energy - put out by the alternator and battery to be converted to other forms by the starter motor, lights, spark plugs, etc.

Some forms of energy are easier to store than others--such as chemical and thermal. Some forms are easier to move around--such as electrical and chemical. And some forms are more readily usable--such as mechanical and thermal. So you can see the need for being able to convert from one form to another.



POWER IS THE RATE AT WHICH ENERGY IS CONVERTED. If one automobile has a higher power rating than another, it can convert chemical energy to mechanical energy at a faster rate. That means it can obtain mechanical energy faster. It can have a higher rate of acceleration.

Different units are used for measuring energy in different forms. The rate at which energy is converted also has several units.

ENERGY = POWER X TIME

1 JOULE = 1 WATT X 1 SECOND

The universal unit of energy is the joule (pronounced jewel). When one joule of energy is converted from one form to another in one second, the rate of conversion is one watt.

1 BTU = 1055 JOULES

1 CALORIE = 4.2 JOULES

1 KILOCALORIE = 4200 JOULES

When measuring thermal energy, the unit used may be the British thermal unit (BTU), or the calorie. The energy content of food is measured in Calories with a capital C. A food Calorie is equal to 1,000 small calories, or one kilocalorie.

When measuring the rate of conversion to or from mechanical energy, the unit of power used may be the horsepower.

$$\text{POWER} = \frac{\text{ENERGY}}{\text{TIME}}$$

$$1 \text{ WATT} = \frac{1 \text{ JOULE}}{1 \text{ SECOND}}$$

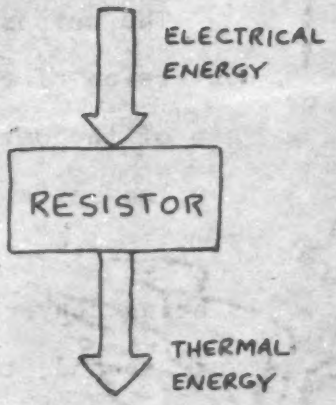
The electrical energy that you buy from the electric utility company is measured in kilowatt-hours. You convert that energy to other forms at a rate measured in watts for lights and heaters and horsepower for motors.

1 HORSEPOWER = 746 WATTS

1 KILOWATT = 1000 WATTS

ELECTRICAL ENERGY TO THERMAL ENERGY

When the electric current output of an alternator is in a resistor electrical energy is converted to thermal energy. The electrons give up some of the electric potential energy that they acquired in the alternator and the resistor gives off heat. As a result there is a potential drop (or a voltage drop) across the resistor.



A RESISTOR CONVERTS ELECTRICAL ENERGY TO THERMAL ENERGY.

The rate at which electrical energy is converted to heat is measured in watts. When electrons flowing at a rate of one ampere lose a potential of one volt, the rate of energy conversion is one watt. If that rate of conversion continues for one second, the energy converted will be one watt-second or one joule.

POWER = VOLTAGE x CURRENT

$P = E \times I$

1 WATT = 1 VOLT x 1 AMP

Find the power rating of a lamp which has a current of 5 amps through it and 12 volts across it. How much energy will it convert in 24 hours?

P = E X I
= 12V X 5A
= 60 watts

Energy = Power X Time
= 60 watts X 24 hours
= 1,440 watt-hours
= 1.44 kilowatt-hours

EXPERIMENT NO. 10

RESISTIVE HEATING

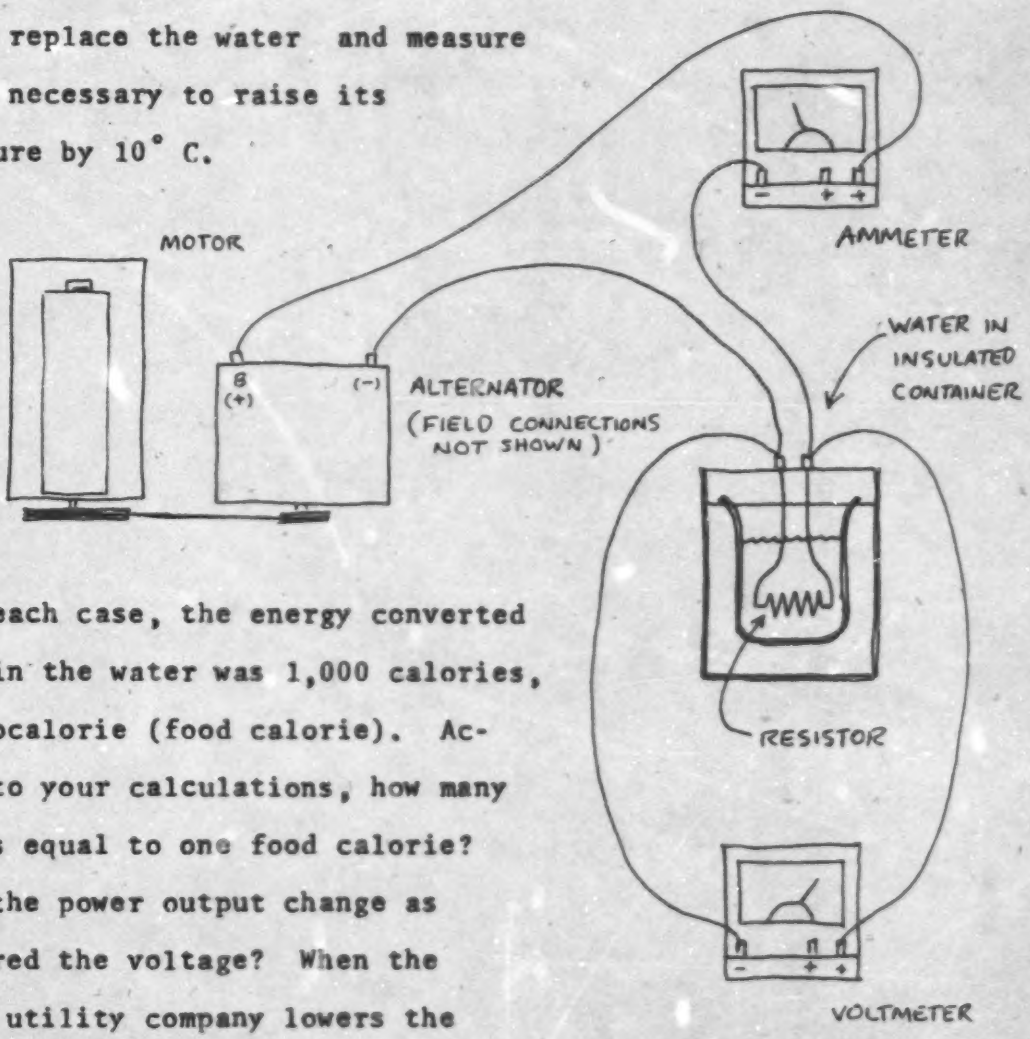
The purpose of this experiment is to introduce you to the conversion of electrical energy to thermal energy and the relationship of the units of both.

The basic unit of electrical energy is the joule. When one joule is being converted to another form every second, the rate of conversion (or power) is one watt. When large amount of electrical energy are converted, it is measured in kilowatt-hours. One kilowatt-hour (kwh) is equal to 3,600,000 joules.

Hook the output of the alternator to a resistive heater immersed in 100 grams (100 milliliters) of water at room temperature. The resistive heater should have a resistance of about 5 ohms and a power rating of about 30 watts. Hook up a voltmeter and ammeter to measure the output of the alternator. Keep the voltage at 12 volts or less. Using a thermometer and a watch, determine how long it takes to raise the temperature of the water by 10°C.

Slow the alternator down to reduce the output voltage by 2 volts and again measure the time it takes to raise the temperature of the water by 10° C. Start with the water at room temperature.

Once again reduce the voltage by 2 volts, replace the water and measure the time necessary to raise its temperature by 10° C.



In each case, the energy converted to heat in the water was 1,000 calories, or 1 kilocalorie (food calorie). According to your calculations, how many joules is equal to one food calorie? How did the power output change as you lowered the voltage? When the electric utility company lowers the voltage at your house (a brown-out), how does it affect your power? Does it make you use less energy?

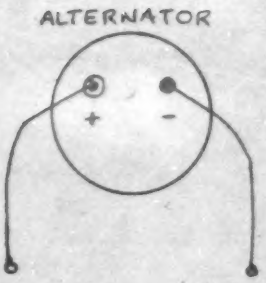
POWER = VOLTAGE × CURRENT

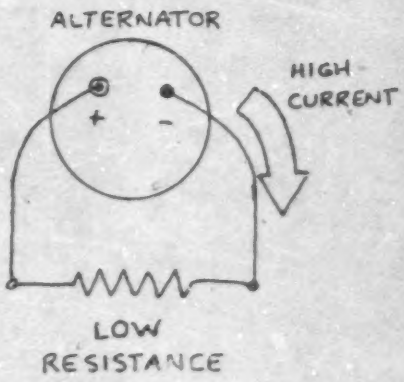
ENERGY = POWER × TIME

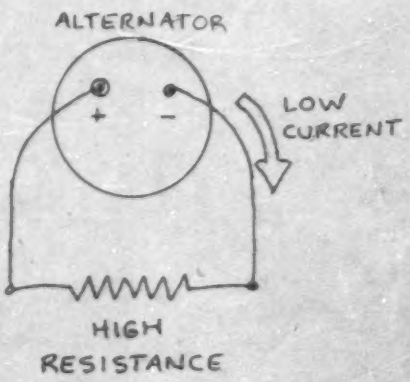
FILL OUT THE LABORATORY DATA SHEET

When the alternator is running but not connected to an electrical load*, the voltage at the terminals depends on the field current and speed. If that terminal voltage is held constant, the current that the alternator supplies a load depends on the resistance of the load. If the alternator is supplying several electrical devices, the power that each one receives will depend on its resistance and how it is connected into the electrical circuit.

An electrical circuit consists of the sources of electricity, the electrical loads, and the wires, switches, etc., used to connect them together. Many electrical circuits can be classified as series circuits or parallel circuits.

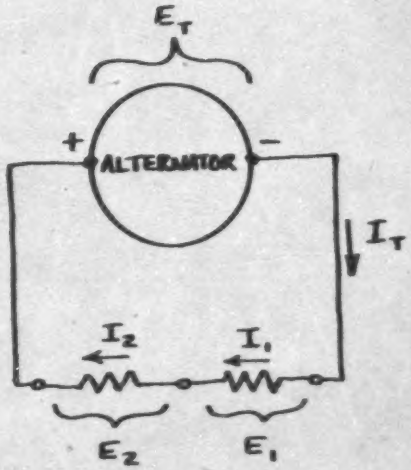






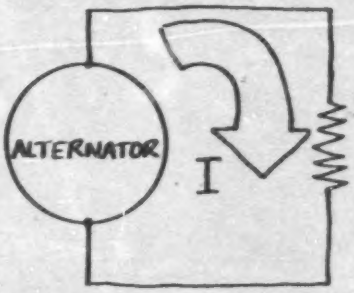
*An electrical load is a device or group of devices that use electrical energy.

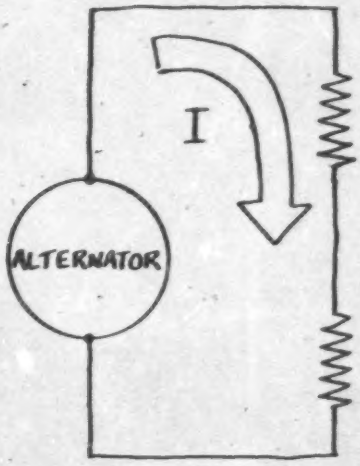
IN A SERIES CIRCUIT THE DEVICES ARE CONNECTED TOGETHER SO THAT THE CURRENT IS THE SAME IN ALL PARTS OF THE CIRCUIT. The electrons only lose part of their potential at each resistor. The potential difference created by the source of electricity is equal to the sum of the potential differences (voltage drops) at each resistor. If the voltage of the source is not changed, adding a series resistance will reduce the current (and the power). Reducing the series resistance will increase the current (and power).

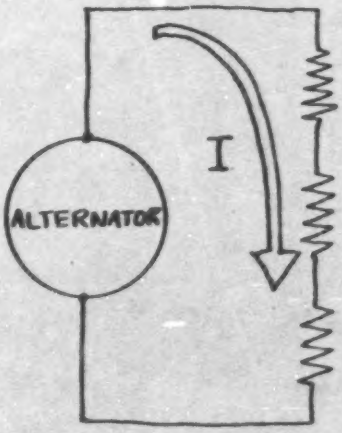


$I_T = I_1 = I_2$

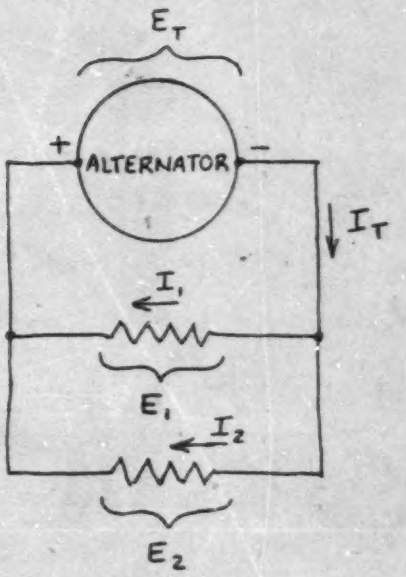
$E_T = E_1 + E_2$





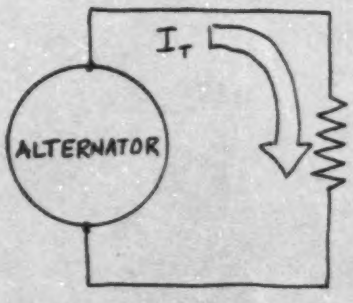


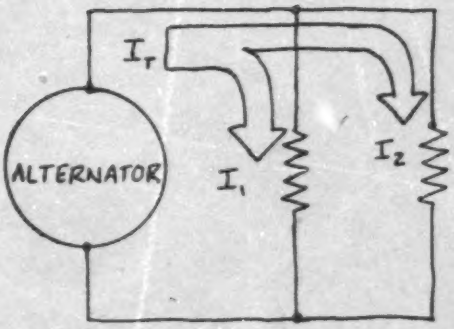
IN A PARALLEL CIRCUIT THE DEVICES ARE CONNECTED SO THAT THE SAME VOLTAGE EXISTS ACROSS EACH OF THEM. The flow of electrons from the source of electricity divides up and part of them flow through each resistor. The current at the source is equal to the sum of the currents at each resistor. If the voltage of the source is not changed, adding a parallel resistor will provide an additional path for current and the total current (and power) will increase. Taking a resistor away will decrease the total current (and power).

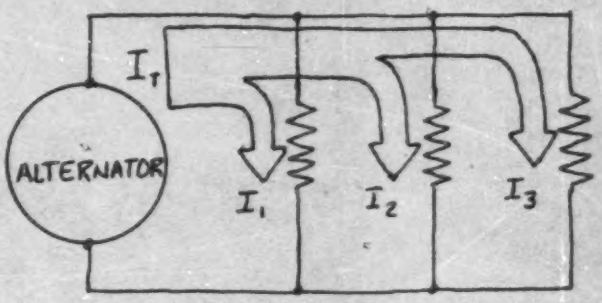


$E_T = E_1 = E_2$

$I_T = I_1 + I_2$





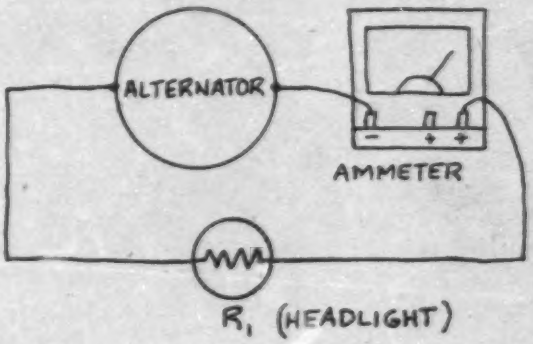


EXPERIMENT NO. 11

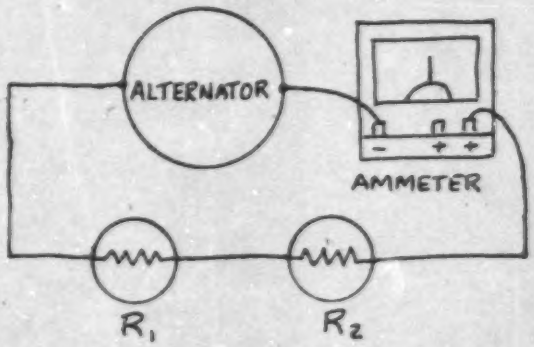
SERIES AND PARALLEL CIRCUITS

The purpose of this experiment is to show you how the power output of an alternator varies as you add series resistors and parallel resistors.

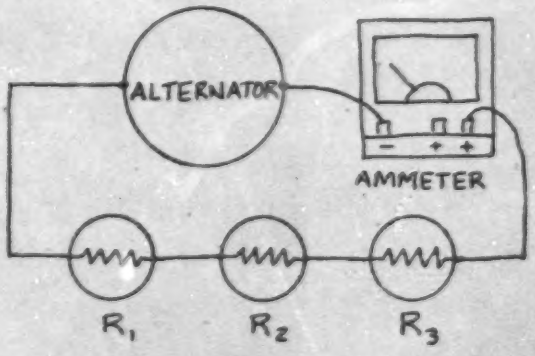
For this exercise, operate the alternator with 0.5 amps field current and 12 volts output voltage. If the voltage changes when you change the load, adjust the speed control to bring the output back to 12 volts. You are the voltage regulator.



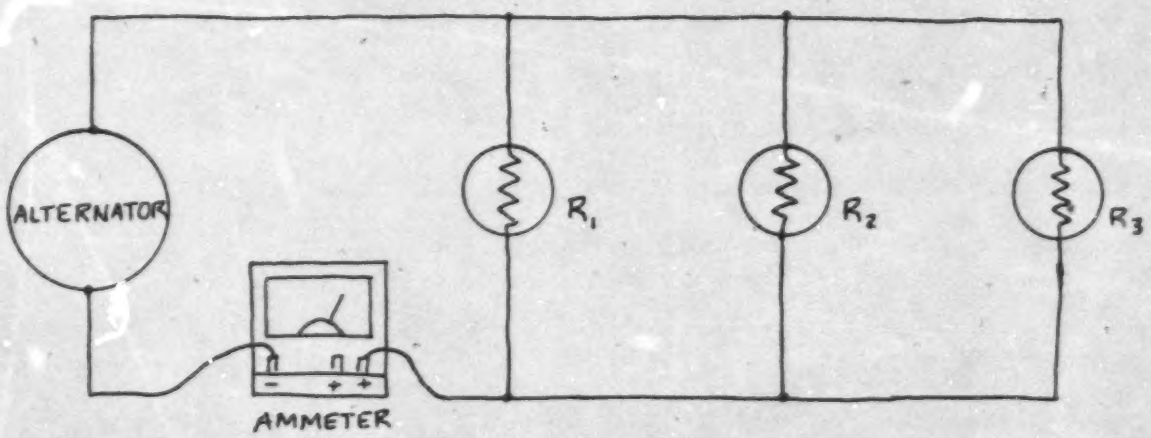
Connect one 12 volt headlight to the alternator. Measure and record the current in the headlight and the voltage across it. Connect another headlight in series with the first. Record the current and voltage at each headlight. Connect a third headlight in series. Record the voltage and current at each headlight.



How does the total power output of the alternator change as series loads are added?



Disconnect all the headlights and start building a parallel circuit by reconnecting one back to the alternator. Record the current and voltage. Connect a headlight in parallel with the first and record the current and voltage at each one. Connect a third headlight in parallel and record all currents and voltages.



How does the total power output of the alternator change as parallel resistors are added?

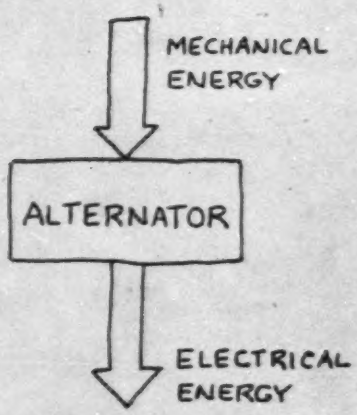
FILL OUT THE LABORATORY DATA SHEET

MECHANICAL ENERGY TO ELECTRICAL ENERGY

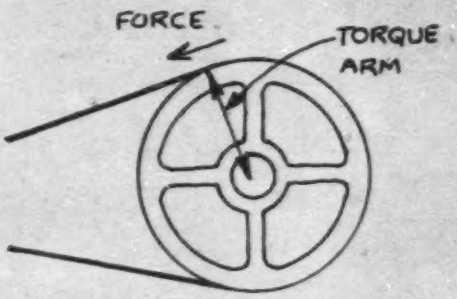
In order for an alternator to put out electrical energy, mechanical energy must be put into it. The mechanical energy input to an alternator is the energy required to turn the shaft on which the field coil is mounted. A force must be applied to the shaft that causes a rotating motion. THE MEASURE OF THE TURNING EFFORT OF A FORCE IS CALLED TORQUE.

The amount of torque applied to a shaft is equal to the force exerted times the perpendicular distance from the force to the center of rotation. The energy input to the shaft is equal to the torque times the angle through which the shaft turns.

It is usually more important to consider the power input rather than the energy input. THE POWER INPUT IS EQUAL TO THE TORQUE TIMES THE SPEED AT WHICH THE SHAFT TURNS. So, to increase the mechanical power input to a shaft, exert more force, use a longer torque arm, or turn the shaft faster.



AN ALTERNATOR CONVERTS MECHANICAL ENERGY TO ELECTRICAL ENERGY.



THE FORCE OF FRICTION BETWEEN THE BELT AND THE PULLEY CREATES A TORQUE ON THE PULLEY.

TORQUE = FORCE x TORQUE ARM

ENERGY = TORQUE x ANGLE

$$\text{POWER} = \frac{\text{ENERGY}}{\text{TIME}}$$

$$\text{POWER} = \frac{\text{TORQUE} \times \text{ANGLE}}{\text{TIME}}$$

POWER = TORQUE x SPEED

EXPERIMENT NO. 12

CONVERTING MANPOWER INTO WATTS

The purpose of this experiment is for you to feel the increase in mechanical power necessary when the electrical load on the alternator is increased.

Attach a hand crank to the end of the shaft on the motor. You should be able to make the field coil of the alternator spin by turning the crank.

Turn the crank with no load connected to the alternator and no field current. Where is the mechanical energy going that you are producing? Put a field current of 2 amps in the alternator. Turn the crank again. Is there any difference? Why or why not?

While turning the crank (with a field current of 2 amps) connect the positive and negative terminals of the alternator together. Describe the result. Where is your mechanical energy going now?

FILL OUT THE LABORATORY DATA SHEET

EFFICIENCY

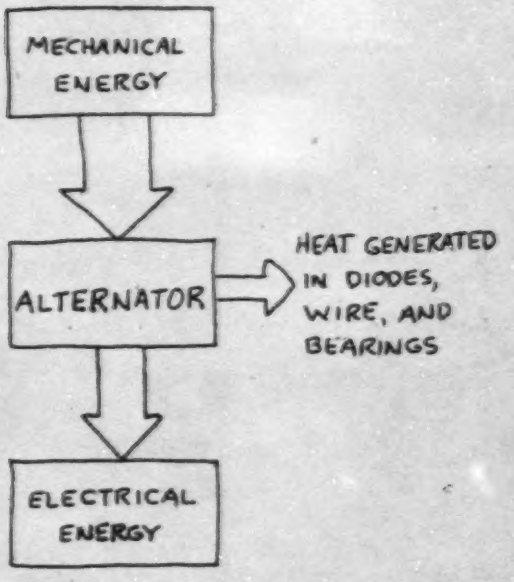
If all the mechanical energy put into the shaft of the alternator came out as electrical energy, we would say that the alternator is 100 percent efficient. EFFICIENCY IS A MEASURE OF HOW WELL A DEVICE CONVERTS ALL ITS INPUT ENERGY INTO THE FORM THAT YOU WANT.

Whenever energy is converted from one form to another, however, two things can happen.

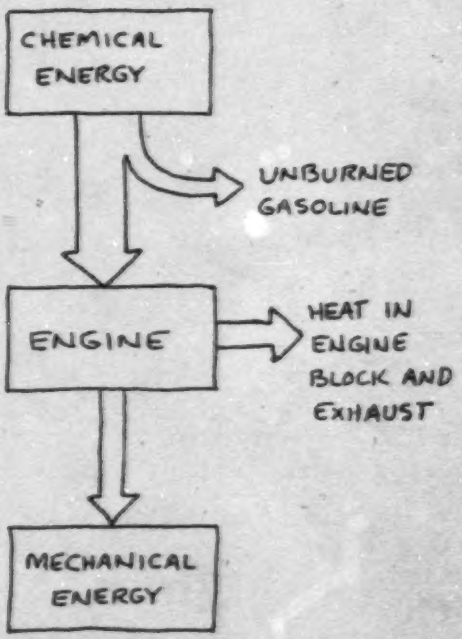
1. The conversion will be incomplete, as in the burning of gasoline.

2. Some unwanted heat will be produced due to friction between moving parts or the electrical resistance of conductors.

In the alternator, we are most concerned with the production of heat. The heat produced in the bearings, in the armature windings, and in the diodes could cause damage. The parts most easily damaged by heat are the insulation (a varnish) on the wires and the semiconductor material in the diodes. Air flow around and through the alternator carries away the wasted energy.



ENERGY TRANSFORMED AND LOST BY ALTERNATOR



ENERGY TRANSFORMED AND LOST BY GASOLINE ENGINE

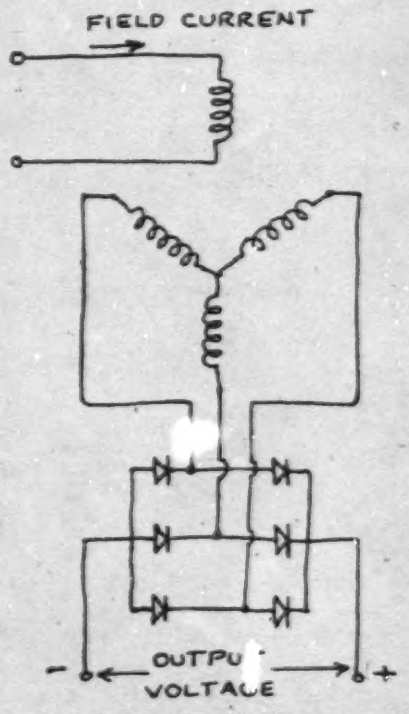
EXPERIMENT NO. 13

ENERGY LOSS IN THE ALTERNATOR

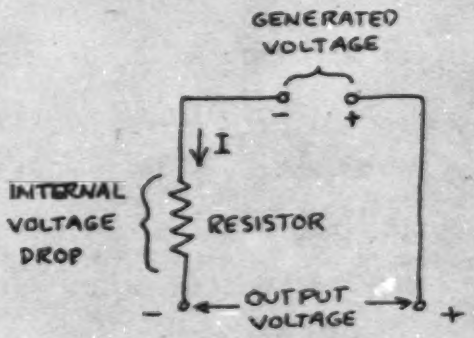
The purpose of this experiment is for you to determine how the rate of energy loss in the alternator is related to the power output and where the lost energy goes.

The conversion of mechanical energy into heat in an alternator is a very small part of the energy loss. Well-lubricated bearings reduce the friction losses to almost nothing. The conversion of electrical energy to heat accounts for almost all the alternator's energy loss.

The circuit inside of the alternator can be thought of as a source of voltage in series with a resistor. (This is a simplification only--not the real circuit). Generated voltage depends only on the field current and the speed. The output voltage is the same as the generated voltage when no load is connected to the alternator. When a load is connected and a current exists, the output voltage is less than the generated voltage. There is a voltage drop, or loss, inside the alternator.



THE REAL CIRCUIT INSIDE THE ALTERNATOR

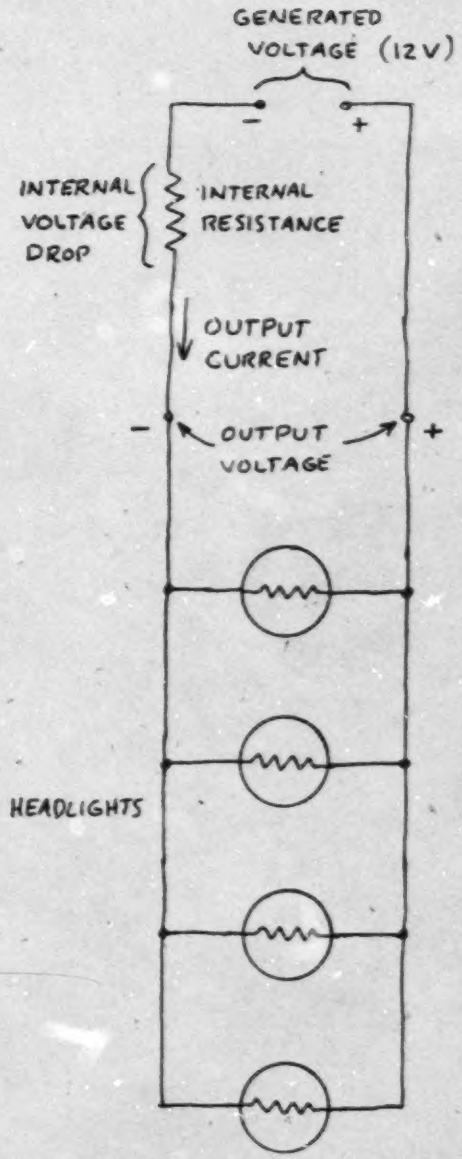


A SIMPLE VIEW OF THE CIRCUIT INSIDE THE ALTERNATOR

Start the alternator with no load connected and a field current of 0.5 amps. Adjust the speed for an output voltage of 12.0 volts. Check the speed with a tachometer and make sure it does not change during the experiment. By holding the field current and speed constant, we keep the generated voltage constant.

Connect four headlights in parallel with the alternator, one at a time. Record the output voltage and current after the addition of each headlight.

As the load current increased, the output voltage dropped. Since the generated voltage did not change, the internal voltage drop must be increasing. The power loss in the alternator is found by multiplying the internal voltage drop times the output current.



Power Output = Output Voltage X Output current

Internal Voltage Drop = Generated Voltage-Output Voltage

Power Loss = Internal Voltage Drop X Output Current

Total Power = Power Output + Power Loss

How does the power loss vary as the load is increased? The total electrical power increased as the load was increased. Since the speed of the motor was constant, where did the additional mechanical power come from?

The internal resistance is actually a combination of the armature windings and the diode resistance. Feel the alternator housing to get an idea of the heat generated in the armature windings. Now feel the ends of the diodes sticking through the back of the alternator. Do you see why air flow through the alternator is important?

FILL OUT THE LABORATORY DATA SHEET

UNIT IV, LABORATORY DATA SHEET

Sheet 1

EXPERIMENTS NO, 10,11,12, AND 13

Name_____

Date_____

EXPERIMENT NO, 10

RESISTIVE HEATING

Trial	Output Voltage (Volts)	Output Current (Amps)	Electrical Power (Watts)	Time (Seconds)	Electrical Energy Converted (Joules)
1					
2					
3					

1 Food Calorie = _____Joules

When the voltage is lowered while the load does not change, the power _____.

How does a brown-out affect your power use?_____

How does a brown-out affect your energy use?_____

EXPERIMENT NO, 11

SERIES AND PARALLEL CIRCUITS

	One	Two in Series		Three in Series		
	R_1	R_1	R_2	R_1	R_2	R_3
Current						
Voltage						
Power						

How does the total power change as series loads are added?_____

	One	Two in Parallel		Three in Parallel		
	R_1	R_1	R_2	R_1	R_2	R_3
Current						
Voltage						
Power						

How does total power change as parallel loads are added?_____

UNIT IV. LABORATORY DATA SHEET

EXPERIMENT NO. 12

CONVERTING MANPOWER INTO WATTS

With no field current and no load, where does your mechanical energy go as you turn the crank?_____

_____

What difference does the field current make? Why?_____

_____

What effect does connecting the terminals of the alternator together have (as you turn the crank?)_____

_____

Where is your mechanical energy going?_____

_____

EXPERIMENT NO. 13

ENERGY LOSS IN THE ALTERNATOR

LOAD	GENERATED VOLTAGE	OUTPUT VOLTAGE	OUTPUT CURRENT	OUTPUT POWER	INTERNAL VOLTAGE DROP	POWER LOSS	TOTAL ELECTRICAL POWER
NO LOAD	12.0 V	12.0 V	0	0	0	0	0
1 HEADLIGHT	12.0 V						
2 HEADLIGHTS	12.0 V						
3 HEADLIGHTS	12.0 V						
4 HEADLIGHTS	12.0 V						

How does the power loss change as the load is increased?_____

_____

When speed does not change, where does the additional mechanical power come from?_____

Why are the diodes mounted on a heat sink?_____

_____

Why is air flow through the alternator important?_____

_____

UNIT IV. AUDIO-VISUAL MATERIALS

Use the audio-visual materials and then answer the questions below.

1. "Energy Conversion", a slide-sound program.

UNIT IV. REVIEW QUESTIONS

1. What types of energy are being converted when an alternator is operating connected to a resistor?

2. How are power and energy related? Name some units of each.

3. Calculate the energy output, in watt-hours, of an alternator operating at 12 volts and 20 amps for 8 hours.

4. Draw a circuit containing an alternator and three 2 ohm resistors in series.

5. Draw a circuit containing an alternator and three 2 ohm resistors in parallel.

6. Which of the circuits that you have drawn will use more power?

7. How can you increase the mechanical power input to a shaft?

8. Why is an alternator not 100% efficient?